Table of Contents

Table of Contents 1

CAVE Legacy 6

Waino (Maksutov?) null test 7

Addictive Nature of Premium Mirrors 8

All Test Methods Should Agree 9

- **Knifedge Test** 10
- **Suiter Digital Knifedge Test** 11
- **Interferometry** 12
- **Astigmatism Testing** 13

Figuring - Humidity and Evaporation 14

Primary Mirror's Aluminum Reflectivity Life Span 15

All methods of test should agree (Part 1) 15

- **Astigmatism and the Test Stand** 16
- **Test Stand Pinch** 20

All Methods of Test Should Agree (Part 2) 22

- **Robo Foucault a second calibration result** 23
  - "Robo Foucault Testing System" 25
- **Test stand deflection/ interferometry gone wrong** 25
- **Test stand deflection/ color surface map** 26

phaseshift10 28

Just for Fun 29

NYC resident would like a sample view thru Z optics 29

The Ronchi Project 29

Testing Methods Agreement 30

What is the most gut wrenching sound on earth? 30

Carl A Personal Insight 31

Mirror cells - some professional literature and ideas for amateurs 32

- **24 inch Thin Blanks** 33
- **Edge Thickness** 33

True Field of View (TFOV) Limit 34

Uzbekistan ATMs 37

- **TFOV Limit** 37

Shop Tour Photos 38

- **Shop Tour** 38
  - Pans Under the Turntables 38
  - Slurry Feed Systems 39

Movies of the System ... 40
Server Space for Videos ... 40
VIDEO ... 40
Mirror Making Video w/Carl ... 40
Painting on the group page ... 41
Shop Humidity ... 42
Humidifiers ... 42
Roof Top Sprinkler ... 43
Crazy Ed and his wife Carol ... 44
Turned Down Edge (TDE) ... 44
TEST METHOD AGREEMENT ... 49
Turned Up Edge ... 50
Jupiter webcam image/"Calling Mike Harvey" ... 51
Zambuto vs. Kennedy mirrors ... 53
Chipped Mirror from Shipping ... 55
Will Scopes Beyond 14" Show More Detail on Planets? ... 56
Pegasus First Look ... 59
Fused Silica... ... 60
Quartz secondary ... 65
ZOC 12.5" F/5.75 Sale Pending ... 66
Mac formatting/Yahoo compatibility (OFF topic) ... 66
Using a Paracorr with an 11" f/5.4 ZOC Mirror ... 67
Saturn Image Wes Higgins ... 67
10" f/6 CZ Mirror ... 68
Magnification Breakdown Theory ... 69
Friendships over time in astronomy ... 70
Quartz Secondary ... 70
1/8 Wave Secondary is Good Enough ... 71
Prisms ... 71
Secondary Testing ... 72
Flat Tester photos are on line. ... 73
Confessions of a ... (closet refractorphile) ... 73
West Coast Astronomy Artist ... 73
Elliptical grinding and polishing strokes ... 74
Surface Roughness ... 75
Rough Surface Mirror ... 75
"Mirror Quality" ... 76

Interferometry **79**
Mirror Documentation **81**
New Interferometry Discussion Group formed at Yahoo **83**
Accuracy of Foucault Testing **83**
Interferometry and a Mote of Dust (OK - Fleck of Paint) **87**
New Certification Coming on line (Official Announcement) **87**
ZOC Mirror Performance Guarantee and Authentication. **89**
Measurements **90**
New mirror certificate 91
New certification and end of an ERA 94
14.5" F-4.3 Starmaster **95**
Thoughts on recent posts (VERY LONG and Rambling) **95**
Performance at the Eyepiece **97**
Mote of Dust (OK - fleck of paint) **98**
Synthetic Optical Pitch **99**
Checking for Astigmatism w/ Foucault **99**
16" F5 Plate Glass Figuring Observation **100**
Inspecting the Edge **102**
12.5" f/6 ..... **103**
ATM list **103**
Sixtests and Millies-Lacroix (was: ATM list?) **105**
References **109**
Choosing a Criteria RMS- or RTA **110**
Choosing a criteria- RMS or RTA (for serious-minded students) **116**
New 14.5" Starmaster with Zambuto **119**
Testing Mirrors again **120**
Autocollimation Testing **122**
New 14.5" Starmaster with Zambuto **123**
New 14.5" Starmaster with Zambuto **124**
Mirror Polishing and Figuring **124**
A Shop Visit - Thank You Carl **126**
Mirror Polishing and Figuring **126**
Mirror Group Birthday **127**
Lifetimes of Various Coatings **127**

How Much Overcoat 128
Black Rouge Polish 129
Figuring & Frequency of Cold Pressing? 130
Birth of the Spreadsheet 131
How to Decide Where to Remove Glass When Parabolizing 132
Carl' Offer 133
ML First 134
Number of Zones 135
The Mirror Makers Spreadsheet 135
Figuring Laps 136
First ML Spreadsheet 139
Mirror Makers Spreadsheet (instructions) 140
Number of Zones 142
ML Plot is POINTS 143
Pitch and Crushed Walnut Shells 147
Polarizer Stress Test - Quarter Wave Plate 147
Mask Zones and Spreadsheet Design 148
Spreadsheet 153
Submerged Polishing Question 153
Machine Figuring 154
Machine Figuring and the Edge 155
Telescope Mirror Making Spreadsheets 159
Mirror Makers Spreadsheet Functional 159
Mirror Makers Spreadsheet Functional- astigmatism 160
Functional Requirements 160
Measuring Astigmatism with KE Test 161
Measuring with Foucault How? 165
Changing Center Mark 166
Figure & Contrast / Auction Astromart 167
Minutes and Micro inches 167
Discipline in the Spreadsheet Project 170
OK, How About Some Data 173
ML and Wavefront 175
Good timing 176
"The Little Thingy" 176
Figuring Preston's Mirror 178
Figuring Preston's Mirror (1st iteration in file folder) 180
Figuring Preston's mirror (1st iteration re-measured) 182
Cerium Pump 183
Pyrex versus Plate Glass 183
Aluminum Lap Thickness Guidelines 184
Radius of Lap to Match Radius of Mirror an Important Factor? 184
Grinding Tool 185

Difference Graph....187
How About a "Progress Graph"....188
Stroke, Offset and Lap Size....191
Preston's Next Session (Reconsideration)....192
Finally measured my Galaxy 18 mirror....192
Figuring discussions (are we moving fast right now, or what?)....193
Commercial Mirror and Tests....195
KE Foucault testing with CCD camera and source of possible errors....196
Carl, How do YOU use the 7 zone spreadsheet....196
Preston's testing....197
Preston's testing....199

How we use the spreadsheet- real world figuring progression....199

Production cost - North America vs. Overseas....200
Real world figuring progression (Preston's slit less Foucault testing)....200
Number of Laps Used....202
How we use the spreadsheet- set 7 and next lap size to use....202
How the Sweet Spot Works....204
Underwhelmed with the Spreadsheet?....204

Figuring Concept....206
ML Graph is Used to Figure Mirrors....207
An important point concerning measuring....208
Figuring lap preparations....209
Movie of Figuring....211
Slit Foucault Tester....211
10 Inch F6.5 Progress....211
Images of Zone 5 Null, + .001" (gray scale problem)....213

Aluminum vs. HydroStone....214

Large Aperture Mirrors....215

Laps....217
Lap preparation and theory- trimming and dressing ZOC-style....218
Quill has ¼ inch Ball End....218
Reuse Pitch....219
Lap Area of Most Effect During Figuring....220
Images of Zone 5 Null, + .001" (gray scale problem)....221
Time for me to get started....221
Five zone spreadsheet available (was: 10 Inch F6.5 Progress)....225
How to Achieve Surface Smoothness?....225
Cerium....225
Eccentric Speed....225
Lap....225
Weight on the Quill....226
Wet Surface....226
Number of Facets....226
Preston's Facts....227
A question from Carl/ (Is your mirror worth $50.00?)....227
Zone 6 still a problem, Spreadsheet update....229

CAVE Legacy

Phillip: I for one wish to thank you for very nicely written history on Tom and the Cave Optical Company. I was unaware of his passing, and am somewhat surprised that it seems to me the event went with little announcement or fanfare. I wonder did one of the major magazines make an announcement or do an article? Cave Optical Company was a major integral part of amateur astronomy for many, many years; they should not be easily forgotten. I had one Cave mirror I bought out of an Astrola telescope that was in Earl Watts' shed. It was a 10" F/7 dated 1972. I used it for a while as-is and enjoyed it, however the image began to break down at 250X. Those were before the days I was measurement-capable, but it looked like it had a smooth figure with overcorrected outer zones. After a while I finally refigured it and put a new coating. I built my "dream scope" with a 10" F/7 tube Dobson. It had a single curved vane spider, the entire interior was lined with black velvet, and it had a 14" light shroud on the end and an annular baffle on the back. It was an extremely high-contrast telescope, the hit of the party at Glacier Point public nights when we went to Yosemite with it, with the Tri-Valley Stargazers, my then local astronomy club. It was big and bulky, but did so many things so very well. Later I sold it to a former Perkin-Elmer employee who had a full set of Clavé eyepieces. I think he was happy with the scope. Anyway, I wandered (sorry). I never met Tom Cave, but heard a lot about him, and Mr. Herring. If anyone wants some first-hand history they might ask Larry Hardin. Larry worked in the Cave optical shop as a helper (I think Larry told me he cleaned up the place) while Alika was figuring mirrors. Now Larry fabricates the Astrola mirror, which name he has purchased the rights to. I will mention that in my estimation the Astrola mirror not only lives up to the reputation, but also exceeds it. Anyway, "Here's to Tom Cave!" CZ

Hello All, I'm glad that my posting of some Foucault graphs and thoughts on mirrors by The Cave Optical Co. were not deemed too far off topic. Several follow up questions were asked. I am not the original owner of either of the mirrors mentioned, nor of a couple of others from Cave that I own. All that I have seen have the company name, date of production, and a serial number; not all have any individual maker's name. Thomas R. Cave III was quite a prolific mirror maker. Reliable biographic information says that he made more than 900 mirrors and sold them in the Los Angeles area before he started the Cave Optical Co. in 1950 (with his father T.R.C. II). During the 30 years of operation, that company is said to have made some 83,000 primary mirrors, including refiguring other's mistakes. Complete OTAs totaled over 16,000. During its last decade (1970s) they had 30-35 employees of who 8 figured mirrors and objective lenses. Alika Herring left Cave in the 1960s, I think; Sky & Tele did a nice bio on him some year’s back. If you look at their magazine ads in the mid 1960s, Cave Optical was in the same league as Star-Liner and The Optical Craftsmen. These upscale makers were smaller than the likes of Criterion, Questar, A. Jaegers, Edmund Scientific, and of course Unitron. Cave had some serious competition in this crowd; I think there is a lot of consensus that they held to pretty good quality standards right up until the late 1970s. Even my later mirrors give rather good images. The only bad one that I know about belonged to a friend. It was a

very late 12.5" f/6, and my friend was serious about Jupiter. He had a small specialist refigure this mirror to near Zambuto standards. Tom Cave had to sell his company in 1980, but he remained active as an optical instrument builder at Hughes Aircraft and later Perkin Elmer, retiring in 1988. He collected meteorites, made drawings of Mars, and remained quite active. He passed away on June 4, 2003. I like to think that his spirit and philosophy live on in places like this. For those who want to know more about those daring days of yore, there is a small Yahoo Group for Cave telescope fans. They have plenty of pix and some good informative links. Regards, Phillip H.

Waino (Maksutov?) null test

The Waino Null Test uses a sphere in a setup similar to autocollimation. To null the asphericity of the optic under test the light source and observation points are in different positions along the optical train, I vaguely recall. I do have the information somewhere in hard copy, but must admit I don't recall where it is. It is either in the Telescope Making articles, or the ATM books, or something like that. I would have to do some serious digging to try to find it. For strengths and weaknesses, I believe the test will have similarities to autocollimation. Unlike the autocollimation test I would suspect that the sphere must be very accurate, as opposed to having some power in it not being an issue, as is the case with the autocollimation flat. But spheres are easier to test than large flats, which is a plus. Positioning may also be more sensitive. The major advantage I see is the nulling sphere does not have to be full aperture, but can be significantly smaller. I don't recall the specific, but I think it may be able to perform with as little as 50% aperture. All in all I recall it looked like a very viable test to me. I think Tom Waino used it extensively, possibly including in his fabrication. I once considered creating a set of Waineo spheres, but never followed through. I'm sure that someone on the ATM list knows where the info can be found. If you can tell me the magazine and issue I can look it up. CZ

Does anybody have any information or reference material on the Waino null test? (ATM archives and Google have nothing in detail. They do not enough on which to study, learn, and use the Waineo null test.) Has anybody used the Waino null test? What are its strengths and weaknesses? Why do I ask this? Now that I am translating material from Dmitri Maksutov, I find that he mentions a 'compensating method' for testing of mirrors...and I've been told that this is known as the Waino null test in the English speaking world. Thanks in advance. Tom Krajci Tashkent, Uzbekistan

I received my annual phone call yesterday from an individual in Wisconsin whom I don't know other than to call me up and ask me technical questions. He called three times yesterday, trying to get his head around the concept of how to check for polish on a finished, coated mirror. He really wanted to be able to fully assess the mirror as it was, by some sort of exam. I told him it could not be done. His first question was could he shine a flashlight down the tube at night and tell how good the polish is. Not. No matter how clean it is you just can't do that. It ought to be an astronomical crime to do such things. The mirror will always look bad under that circumstance. We discussed the matter of

looking at the glass face-on, looking for a bright, uniform surface in normal daylight. It seems to us here that are about the best you can hope for with a coating in place. Other than that I told him his best bet was to use the scope side by side with a known quality system and do a contrast comparison test under the sky. That's the bottom line, anyway. It seems to be difficult at best to tell how good a polish is with a coating in place. Yes, we can compare overall appearance side by side looking into two mirrors in normal light. Some look dull by comparison to those who are truly bright, those that look like "deep chrome". But other than that we're not aware of any way to absolutely determine the polish quality with the coating in place.

Case in point: Some time ago I examined a mass-market primary that included being able to strip the coating. I didn't notice anything non-uniform in the polish with the coating on, but as soon as it was stripped and the high-intensity light beam exam in the dark room took place, there was an obvious haze around the edge. It was simply under polished, perhaps only 2 hours by machine. This really wasn't noticed with the coating in place, but was blatant with it stripped off. (The mirror was a popular 8" that sells in the American market in the $200.00+ price range, and is in common tube-Dobs.) By about the third phone call I decided to let him know how complicated this thing really can be, and that he was really just beating his head against the wall in his effort.

I was trying to communicate how many levels there are in this subject, as there can be in any craft or discipline. One example I told him was that there are actually "premium quality" mirrors out there that have gray surfaces when examined without coating under high intensity light. He was flabbergasted, and could not understand how this is so. Then I told him there are many different kinds of cerium that have different purposes, and that some grades are more suited for finish work than others, and so on. I think he finally gave up and realized he would have to assess the mirror under the sky, which was my first suggestion. If anyone has any other input or observation on polish quality and coatings, this might be a good topic to kick around for a day or two. CZ

Addictive Nature of Premium Mirrors

I have seen this more times than I can count. Yes, it is fun when it happens. I have to reply to this because such a scenario still pushes a button for me, as this kind of a story demonstrates a particular kind of ignorance on the subject by the other scope owner who needed that scenario to take place. A higher contrast system performs better in all conditions. A higher strehl ratio/tighter airy disk will show more in many objects under essentially all circumstances. I have told this one story before, but it is so blatant that it serves as a good example.

At Table Mountain a couple years ago we watched a Starmaster 11" show a threesome of galaxies more clearly than a 15" other-brand premium scope with a mediocre mirror in it. The faintest of the three galaxies had to be pointed out to Rick Singmaster by the 15" scope owner. We went back to the Starmaster 11 and it was sitting right there just looking back at us, plain as can be. The reason your planetary story happens so often is because planets are "in-your-face" when the seeing gets good. The effect is unmistakable, and is

"proof" to the "unbeliever". However if folks with Orion XT-10's were pushing their scopes to their limit by looking at faint galaxies for one example, they would see a difference when a high-contrast instrument comes around, even when the seeing is not 600x. They might even see as much as the equivalent of one full size larger in aperture in some cases. I didn't mean to play your story down.

Thank you for sharing it with us, it is a fun story and it still gives me a smile when I see it happen. I think what actually took place is the individual probably had never seen a planet with his own eyes quite like that before, and he wants to be ready next time it happens. Good for him, and good for you for being there, to show it to him! You must be pleased, I am sure :) The other irrevocable truth that this restates to me yet once again is, no matter how many times it is said by so many people, it makes no difference. All the testimonial can do is raise curiosity. To be convinced, one has to actually see it for themselves, with their own eyes. THEN it becomes reality, and is never forgotten. Until that point, it is not reality for the listener. Thanks for the story, Jim. Carl

A quick anecdote: A couple of weeks ago, one of the newer members of our astronomy club, who observes with an Orion XT-10, commented to me that he didn't believe that premium mirrors were worth the price, because "the seeing around here is rarely good enough to make a difference". Well, it took exactly one night of awesome seeing to change his mind. This past Saturday, at our club's monthly observing session, the seeing was spectacular! My 12.5" PB consistently showed Saturn at over 600X with absolutely no image breakdown, and there were great moments at up to 1000X as well. Within 48 hours, my friend had purchased a Z-mirror Starmaster 11" off Astromart. He should be a very happy camper, at least until aperture fever strikes.... ;^) Jim

All Test Methods Should Agree

I've been dancing around this subject and threatening to write about it for months, now. Its finally time, I just have the "itch" to open this can of worms, and a can of worms it may well prove to be. Understand this very long post is a scratch in the surface. There will be more to follow in the days, weeks, etc. to follow. I already told the story some time ago of the late Robert Goff who once said to me that all test methods should agree. I asked him how his knifedge compared with his interferometry and he got one of those twinkles in his eye that I now think fondly of and must admit I miss seeing. When he did that I knew something important was going to happen. He said, "they agree". Well, that confused the hell out of me at that time because I didn't understand how that could be, but at the same time I also knew that I dare not say another word. That statement was meant to stand by itself, and I knew that over time I might be fortunate enough to learn how that could be, if I paid my dues and were a good student. We never spent enough time together for me to learn this directly from him, I only wish that I could have apprenticed in his shop. But it was to eventually be that I would come to understand the differences as well as the similarities through my own experience.

This talk is going to get technical. For the readership that feels completely lost, don't hesitate to ask questions. This subject is pertinent in today's amateur astronomy industry

because it will deal with matters that are hotly debated and have been for quite some time. I remember Todd Gross making a statement in an attempt to reconcile the difference between knifedge and interferometry. He said, to paraphrase, "take the knifedge result and divide by about 2.5 to get the equivalent interferometry result." That was a good approximation. I don't disagree with him. But the question remains, why the difference?

Knifedge Test

The knifedge test, also known as "longitudinal aberration measurement" measures essentially one thing, and that is spherical aberration. It measures in one linear axis across the diameter of the mirror. There are images in the bench image file that show a mask in place. Each zone or mask opening on one side of the mirror represents one measurement. The entire zone is looked at by the operator and matched with its corresponding zone on the opposite side for hue and when the hues match a value is given for that radius. The measurement is taken as a point in the middle of that zone on the glass. That point is then compared with the measurement of all the other points across the radius. Those points are compared with the theoretical parabola and an overall value is given for them. Using simple trigonometry, which is what reduction software does, those points can be used to build a surface profile, which when doubled in amplitude is also the wavefront profile. We know the slope of the glass in each place from one point to the next, and knowing the distance between the points we can also derive the amplitude of that slope. So from the knifedge measurement we can derive the slope and RTA, and we can derive the amplitude of each point, thus deriving the wavefront profile, peak to valley. So what do we have as a result of this capability? We have (a rather accurate representation) of the surface profile along a line across the middle of the glass.

It is important to understand that. This is also known as a 1D, or, one-dimensional measurement. This profile using data reduction can tell us the spherical aberration, given in peak to valley, along that line across the middle. Another way to say it is, we can derive the error in the surface, (or spherical aberration) with respect to the parabola, in wavelengths (or nanometers, or whatever you wish to use). We have stated many times before that such a method can be very accurate in that assessment. Indeed it can, as we will demonstrate in this subject as we go along, but, what about the rest of the mirror? Good question. And herein lies a potential weakness of this test method (keep in mind every method of test has strengths and weaknesses).

The knifedge test is dependent on a smooth surface to be reasonably accurate. Most measurement-based tests are, but this one in particular. It is also dependent on a good figure of revolution, or, stated different, a reasonable absence of astigmatism. That is, there is an assumption made to a degree, that the measurement in another axis along another line will be similar to the one measured, which brings up a point. For those who have the explanation page that accompanies our mirrors, it addresses the fact that we do in fact measure in another axis. For smaller mirrors we take another set of measurements at 90¡ and compare the two sets. This tells us right away how uniform the mirror is, to a reasonable point. On larger mirrors, we take four axes of measurement, so that any

astigmatism that may be present will not escape detection.

Suiter Digital Knifedge Test

Now, back to spherical aberration. Not long ago I wrote about giving birth to new methods of test, and gave the example of the Suiter Digital Knifedge Test. What Suiter compared in measurement with the interferometer is spherical aberration. Dick measured the mirror along one axis, in essence like we do, and compared that value with the spherical aberration of measurement given by the interferometer.

Bingo. It is that simple. I'll leave that there for the moment. I've considered for a long time what to call the stated reduction of the measurement that we use, to best describe it. I have not settled yet on a name. On the doc we say "PV wavefront", because that is the number the industry is used to, whether folks understand it or not. They seem to want that number. Okay, fine. But that number means different things when it comes to different tests. (Key point follows:)

What the knifedge test measures may be best understood to be described as "averaged spherical aberration". That means, essentially 3rd order spherical aberration assumed to be applied to the entire revolution of the mirror, or, all the way around.

Another way to picture it is with the wavefront shell diagram. There is a wavefront shell described in a much earlier posting, with diagrams in the pictures section. (I think the thread is about RTA and wave fronts.) We have drawn a couple of 1/4-wavefront shells with all the slope and height aberrations contained within them. Such a diagram is also in Suiter's book page 7.

What is true for the knifedge test is, (key point #2 follows) all the points measured along an axis on a smooth mirror do in fact exist within that peak to valley wavefront shell along that axis. If we measure 1/15 wavefront along an axis in a 7-zone test, on a smooth mirror those points actually lie within that shell, demonstrating an actual PV wavefront of 1/15 along that axis. It is real, it is true, and it is reasonably very accurate, as we will again demonstrate later in the talk. If we measure another axis, for example at 90^0 and get a result very close, we combine those two values and come up with an averaged spherical aberration of 1/15 wave PV. When we measure a mirror in one axis and get a particular value, then measure a second axis and get an answer very similar, then even measure two more axes at 45^0 and still get very similar values we can be rather certain little of the mirror deviates much from these values, and so can be confident we're not very far off. At some point during this subject I'll upload some images of zonal plots from different axes from actual mirrors, and show what kind of repeats the test and the mirrors can give.

Need DIAGRAMS HERE

But the point here is, when a smooth figure of revolution is measured in multiple axes, all residing within a wavefront shell that has amplitude of 1/15 wave; I would say the mirror shows an "average spherical aberration" (my term) of 1/15 PV.

Interferometry

So how does this square with interferometry? I'll touch on this only briefly today, because I need more "wind" to go another long stretch. Interferometry is a two-dimensional test. Depending on which kind of interferometry it is, and the software used, and the number of data points used, it more or less measures sample points over the entire mirror. In very short, the PV number given by an interferometric test report will give a value for the one highest point on the mirror, and the one lowest point, no matter how small, and no matter where it is. It is not an "average" kind of thing. So for that, the rating will be much more "incriminating", if you will. The interferometer in a peak to valley rating gives a 2-D rating based on every sample point it measures. And yes, typically it will be about 2.5x worse than an average spherical aberration rating given by the knifedge, on a smooth optic.

There is much more to cover here, (yes, Strehl ratio, etc., etc.) and we will get to it in time. But before I sign off of this posting I want to point out something very interesting, that I have never seen dealt with before. There is a question that I see begging itself in all this- Given reasonable figures of revolution, which PV rating of the two test methods will tell you what you will see in the star test? The interferometer? The knifedge? Both? Neither? I'll let the group ponder this one awhile. My answer (FWIW) will come in the next posting. ...When I get more wind. CZ

Good question. If he is willing, I would like to ask Steve Kohler to explain this one, as he is working a lot these days with Zernike polynomials (algorithms for different orders of aberration). I'll ask Steve to try to keep it as simple as possible for the layperson. If he's not available to do that I'll take a stab at it myself, shortly. CZ

Just what is 3rd order spherical aberration? How many orders are there? There is one order for each dimension? Ron

Tom Krajci wrote: Strictly speaking, if we are talking about simple astigmatism (cylinder shape, saddle shape, potato chip shape...call it what you want...but it's not trefoil or higher order astigmatism)...it's possible that the axis of astigmatism could fall at 45 degrees with respect to your two test orientations for small mirrors. If that does happen, then your two test orientations are not sensitive to astigmatism...won't 'see' that particular orientation of astigmatism. Am I right?

Yes, you are correct in this. If I were right, would it be worthwhile to test smaller mirrors at two non-perpendicular orientations? Such as 60 degrees or better yet, use three or more orientations for testing? However, I admit that with smaller mirrors the odds of astigmatism cropping up are far smaller than for larger mirrors. And I agree with that point as well. In our production we have a sense of when there is "trouble brewing".

Given our processes, smaller aperture mirrors generally have much less potential trouble.

We know now at what point astigmatism affects both the star test and the in-focus image. As with just about every other aspect of our trade, we have margins built into everything. Astigmatism is one of them. Generally we're aware of a condition long before it becomes an issue. For the amateur working a one-off mirror measuring four axes is not a bad thing, in fact, it might be recommended. Almost every optic has some degree of astigmatism. There is classic two-foci, then there is localized, higher-order stuff. Given our annealing and glass quality check, and our humidity controls and work conditions, we have classic astigmatism down to very low levels in our small mirrors, and in fact in many cases we can't measure any at all. And if we do sense a problem, we will measure three or four axes to be very certain about it.

The issue for us involving measurement by hand with a knifedge is the energy involved. It takes a lot of energy to do a worthwhile critical measurement, such as in documentation. Given the amount of production that we do, we have to balance the energy spent against the need to do so. We don't measure more than we absolutely need to, as it is expensive in time and energy. But still...testing for 'astigmatism with two 90-measures means you are sensitive to (can detect) only certain orientations of astigmatism. Again, am I right?

Yes, you are correct. We're going to get into this with a very good image for an example, further in this subject as we go along. We're going to look at a well-documented example of primary astigmatism and consider it. And I'll mention one other thing. We also have another test in the system, in the finished telescope in the field. Our customers know how to test at the eyepiece for astigmatism, which is at the "crack of focus" at high power. CZ

Astigmatism Testing

I failed to mention something important about our process with respect to astigmatism. I don't want to give the impression that we think we don't have to check for it because we do. Every mirror at completion of polish in the spherical state goes through a critical astigmatism check. It is done with a Ronchi grating in four different axes of orientation. To pass our criteria, astigmatism cannot be detectable in any of the axes for the mirror to move on to figuring. So any two-foci astigmatism is sent back for further polish as needed. I would estimate no mirror goes on to figuring with any more than perhaps 1/50 wave of classic astigmatism. The Ronchi test on the sphere when done appropriately is very effective for this. CZ

Obviously there will be a lot of questions generated that will run off on tangents as we go through this subject. Be patient with me, (those who are interested in our viewpoint, here) and I'll do my best to give appropriate treatment to all of them. I may only answer one or two per day, so it might take awhile in cases to stay up with it. It appears at this point that the larger subject may proceed slowly. I think that is fine, as it is a very big subject, and I don't know what else we have to do anyway:) There are obviously going to be major and minor offshoots, and probably other major threads spinning off as a result. I like Michael's question below. It’s a good one, as it is information that is not known to every amateur, and I must say not every professional knows about it, either.

Figuring - Humidity and Evaporation

The discussion below applies to *figuring* of glass, as opposed to large-lap diameter polishing. The humidity in the work environment affects the evaporation rate on the glass. The lap acts as a squeegee, wiping clean the edge as it passes over it, and wiping the rest of the surface to a degree depending on how much liquid is on it. As any window washer probably knows, once you wipe a window with a squeegee in a dry environment it "flash-dries" almost immediately. Do the same on a very humid day, such as 90% and see a difference. You will see a thin film of water remain much longer. In a very dry environment the lap when working on top of the glass because of the squeegee effect is going to encounter dry glass. Because of its turning motion, stroke speed, stroke length, and variables ad infinitum, the effect of the lap along the edge for example, will be different from that underneath in the middle.

What I mean in general is, the effect of the wiping of the lap will not be uniform. So the bottom line is, drier glass will cause generally rougher primary ripple that wet glass. That is why some techniques involve polishing under water. For the same reasons, drier glass will also cause non-uniformity in the larger pattern left by the lap, such as different orders of astigmatism. For example if there is non-uniform resistance being made by dry glass along the edge, the lap will begin to produce a non-uniform pattern along that edge. We have found that the higher the humidity in the work environment, the smoother the finished product is, overall. It has better primary surface characteristics, and there is less astigmatism. We fell into this information by watching a pattern develop every summer. The larger mirrors were getting grossly astigmatic in the outer zones. Originally we thought it was the temperature.

Over time with experimentation we learned it was the humidity that did this. After Bob Goff passed away I asked his wife if she knew anything about the humidity he kept in the shop. She right away said yes, he kept it constant at 70°F and 70% humidity. Well, 70% is rather wet for working conditions (no kidding) and we found that indeed at that humidity everything gets smoother. So now we monitor the shop with two hygrometers and have three humidifiers, one evaporative as in a swamp cooler, and two that boil off steam. When we have any astigmatism problems, now the first place we look is at the humidity.

Perspective: The above is more important for larger mirrors, and for sub-diameter work done tool-on-top. I think that for an amateur doing handwork on an 8" mirror MOT that humidity is much less of an issue. Also note that otherwise our processes using the machines will be quite uniform. The stroke arm will draw a uniform pattern of no less than 20 petals (as in a Spirograph pattern) before it approaches a repeat, and even then it is a slight offset. So anytime we see large- scale non-uniformity we look to things like humidity. In short, during figuring the glass likes a WET environment. CZ

Given our annealing and glass quality check, and our humidity controls and work conditions, we have classic astigmatism down to very low levels... OK, my curiosity is piqued. How do changes in humidity induce astigmatism? -- Michael Lindner

Primary Mirror's Aluminum Reflectivity Life Span

Peter, I would say the degradation over time is *not* straight-line. I would suggest the reflectivity is constant until such time as the overcoat deteriorates, and then the coating begins to etch or blotch. You will see it when it happens. As far as I know, the shiny part will always stay shiny, unless water stains or dust obscures it, reside, etc. I don't think a mirror can lose 25% of its reflectivity without you noticing. Your coating is two parts- an aluminum layer and a quartz (glass) overcoat. My understanding is the aluminum stays essentially at same reflectivity as long as the overcoat is in place and protecting it. My experience with coatings is that when they degrade, they do it in blotches. Small areas will turn black, or show gray spots. I have mirrors that are now about 10 years old. They appear as shiny as the day they were done, with the exception of a few "fly spots" scattered around where it is etching slightly. At this point it is only cosmetic.

I should add that I have seen very old coatings that were dull and gray. These obviously are in poor repair and need to be redone. I still maintain that one glance at a coating and you can tell very closely what condition it is. It won't give you 25% less uniform performance and you not are aware of it. If you live near the seas and observe in salt air you're going to have a lot more recoats. If you live inland in dry air and only wash every 3 or 6 months, your coating may last well over a decade. It really varies with so many conditions. There is no absolute way to tell. CZ

Often, as I look at my wonderfully reflective and polished and new Zambuto primary mirror, I wonder how long it will keep this general level of reflectivity. I know that some of this depends on the surrounding conditions that it spends its time in when used and stored. If the reflectivity of the aluminum coating slowly degrades over the years, one might not notice this through the eyepiece until taking a look through a neighboring scope that's newer and of similar aperture. One can get used to how things perform even if they slowly degrade. Does anyone have reliable information on the lifetime of usefulness for these kinds of coated first surface mirrors before needing to re-coat with new Al? Is the degradation of the reflectivity over time of a coated Al mirror straight line? At what age does a mirror generally lose 25% of its reflectivity? A 25% difference in light gathering ability is the difference between two differently sized Dobs. This question comes to mind when I see other deep sky observers push the limits with regards to observing threshold objects with their 5-10 year old Dobs. I'm sure that if they re-coated their mirrors, they would spot these threshold objects more easily. Peter Natscher Monterey, California

All methods of test should agree (Part 1)

Steve Koehler wrote: Carl To clarify, don't you mean multiply by 2.5? Thank you for the clarification. I meant divide the *denominator* of the fraction by 2.5. Later in the article you say that interferometry tends to give a worse PV error than a knife- edge test. So, a 1/10-wave mirror, as reported by the knife-edge test, might by a 1/10 * 2.5 = 1/4 wave mirror under interferometry.

understood the importance of slope error, and knew what the hell he was doing. CZ

Astigmatism, both primary and localized, inside of a certain tolerance will also not be picked up in the star test. Carl, what is that is that tolerance? Dan

Robo Foucault a second calibration result

Dale, Thanks for your posting. It sounds like you're doing some promising work. I wrote recently on "birthing new methods of test" and what my personal/professional viewpoint on the subject is, that is, how it should be handled. If you were interested, my suggestion would be that you get a reference of absolutely known value, documented by the most authoritative source available to you. It should have in one case an F/ratio equal to the fastest mirror you intend to test with the method (F/7.5 has relatively little knifedge shift in it). The test then needs to mimic the standard knifedge test. A total PV wavefront number is not sufficient, in my estimation, as you can wildly vary zonal plots from one test to another and get a same wavefront value. (One could even be overcorrected and one under corrected by same amount, which is an invalid result). The way I would approach this is to use a graphical zonal plot, preferably the knifedge shift with respect to the Millies-Lacroix envelope, and overlay the plots from your testing system with the plots from a standard Foucault test to make the comparison. The goal is to get zones that consistently match within a couple thousandths on a fixed source tester. And that is the key- thousandths of an inch on the micrometer at the radius of curvature. That is where the sensitivity lies, and that is what makes-or-breaks the result. I'll upload an example. In our new folder in the Files section (test method agreement) find a newly constructed image titled "***Foucault Overlay***". In the three M-L graphs pictured we have three different test runs on a same optic. The mirror in question is one of our 12.5"ers at F/4.5. We supplied it as a potential reference to an individual attempting to design an automated testing system. These graphs are examples of how I conduct knifedge test comparisons, whether they are manual, automatic, video, or what-have-you. No difference, the results should be same. Looking at the top graph you will find what we see in-house. There are two sets of zonal plots one overlaid on the other. They represent our measurement of the mirror in two axes of orientation, 90¡ apart. There is only one zone with any notable discrepancy, which appears to be a localized aberration. All the rest of the plots are within a couple thousandths on the knifedge, within what we assign to standard deviation errors of measurement. I should mention we performed no testing on this mirror beyond our norm, in that we did not do excessive repeats of measurement runs using averages. The measurement was conducted as we always do, which is one pass in and one pass out in each axis. The second (middle) M-L graph is an interesting story.

Need Image HERE

The blue is our combined, averaged measurements in both axes, which is how we document the mirror (this is the same plot seen on the documentation, which is the combination of the two axes in the top graph). The orange set is a comparison test done by five amateur mirror makers at the local mirror-making group where the individual developing the automated test participates in fabrication and testing. Each amateur mirror

tester did one test run, and then the results of all five were averaged. Now interestingly, the overall PV wavefront deviates no more than about 1/70 wavefront from our final number, which is typical for out-of-house measurement using the same method. We really haven't seen anything worse than 1/50 wavefront deviation from our doc when careful testing was done, unless there was some other reason for the discrepancy. So I do give the amateur testers a high grade for their work, I think they did well. However, is it good enough of a match for passing a test method? I say not.

There are zonal changes that are too far off for a serious fabricator to be willing to rely on. They were actually very good on the outer half of the mirror, and it is just about passable. But the inner half is significantly rougher, with their plots going above, then below ours. There is enough deviation there that if it were important to the development of a test method, both parties would do much more extensive measuring. The bottom graph is the automated method by the individual developing the test as was measured at that point in time. The blue plots are the documentation, and the red are the system in question. I don't need to say more about that graph, except that the deviation could be stated as an overall difference of about 1/3 wave PV. But look at the slope difference 1/3 wave represents. The RTA/Millies-Lacroix graph is very telling of slope errors, and is very sensitive in its display of knifedge shift. That is why we use it as a comparator. I hope you get the idea. What I would do for a first qualifier/calibrator is get a fast *reference piece* and conduct the two different tests in the same axis. I would measure the same orientation and radii of the mirror in both cases, so the comparison is exact. If you get an overlay that looks like the top graph, I would say you're going somewhere and it looks real serious. If you get a result that looks like the middle one I would say there is a sign of promise but it needs work (note that the middle graph does show close to the same overall correction center to edge). If you get one that looks like the bottom, I would say go back to the drawing board and start from scratch.

These simple, visual graphs are very powerful tools. Anyone on this group, whether they are advanced amateur, professional, or layperson, can see very clearly what the comparison is. They may not have a mental scale for it, but that can be explained clearly enough if it is necessary for the demonstrator to do so. I would suggest to anyone and everyone who is doing technical work on this group that whenever possible you make your examples as simple, straightforward, and user-friendly as you can. It will as a result be more effective in getting your point across, because the readership will have far less mental gymnastics to go through to get where you want them to go, and they will stay with you a lot longer, as a result.

One more note, and this applies to the entire subject we are currently dealing with. The Foucault test measures spherical aberration. The graphs you have just looked at are precisely that- indicators of higher and lower order spherical aberration. This is the common denominator we are going to use for all of our tests in this subject, including interferometry- that is, spherical aberration. The star test measures spherical aberration. The knifedge measures spherical aberration. The interferometer does as well, but sometimes we have to do some deciphering to get to that number. What I'm saying is, if we can reduce our data to a number and graph for spherical aberration, we will have a

common denominator that everybody can understand, because they will be familiar with it. When we developed our documentation, we did it with the idea in mind to make it as simple and straightforward AND APPLICABLE as possible. As a result, folks often come to me and say, ÒI have this data here, but it doesn't mean anything to me. How would it look on your documentation? A word to the wise. CZ

"Robo Foucault Testing System"

Hi, I'm Dale Eason. Steve Koehler has been telling you about my Robo Foucault testing system. I had not been on this group but now I am. I would like to tell you about the second calibration apart from his mirror that I completed this week. I have an 8" f7.5 mirror that I figured a few years ago and measured using the standard Foucault and mask method using 5 zones. I learned the method from Texereau's book. It was the second time I figured the mirror. Anyway I got it to what I thought ways about 1/12 wave wavefront error according to TEX software. Measured over two diameters. After getting it coated I star tested it as described in Suiter's book. It did not star test as good as 1/12. It was more like 1/6. After taking it to a local star party and comparing the view with other scopes I can say and others have agreed that it is a very good mirror usually better than many of the others. But that is only a subjective opinion. After making and improving on my Robo Foucault system and measuring Steve's mirror (Steve has posted about those results) I measured my 8" again with Robo Foucault. I tried many combinations of test parameters that I can very (light sources, IR filters, different lenses on the WEB cam) all give me results in the 1/12 Wave range using sixtests to analyze the data. I recently met a person who has made many mirrors and test flats. He also used to teach mirror-making class. He brought over a flat that he uses to test mirrors with and he tested my mirror using the auto collimation tester. The NULL test showed my mirror to be very good with a slight turned edge that my software also showed. He said that from his experience the mirror tests match to the best that he can tell. I now have two mirrors with test data that agree with my tester. I would like to have more because like many of you I have many questions about how reliable it is. I am still not sure why the 8" does not star test as well as it bench tests. The problems may be with the diagonal (which I plan to test using Texereau's method against a sphere) or maybe the Barlow and eyepiece. Or maybe it is my star testing technique to blame. I actually have a third mirror measurement but don't have any hard data for it. Take it for what you will. I have tested a 12.5 F6 mirror that the owner says star tests at about 1/3 to 1/5 wave. But he is just learning the star test. My Robo Foucault system says it is about 1/5 wave. I have only had the mirror for a few hours and it needs to stabilize to my basement temp. So those numbers are very preliminary. Dale Eason

Test stand deflection/ interferometry gone wrong

Carl is "test stand pinch" something that "always shows up? As far as I know, yes. Would smaller mirrors such as a 10" say be immune to this? No. See the mirror at Portaball website on the optics page. Do the vertical graphics flip and watch the change in the shape. It is non- symmetrical in its vertical axis. Is there a size to thickness ratio that would eliminate this? Sorry, I don't think so. The thicker it is, the heavier it is, say a

10" 1.5" thick for example. My thinking is that this does not come into play until you go larger then 10" unless the mirror is very thin. I don't think you're going to be so lucky. For example, my understanding is that Roland Christen has a vertical test setup for his *lenses*. He turns the light path from the vertical to the horizontal for the interferometer using a flat, but he does run the light through the lenses vertically, because even his relatively small optics sag from their own weight when resting on edge. So it appears there is really no getting around it, we have to deal with the fact that our optics sags when sitting on their edge. Isn't it amazing how complicated all this S.H. gets when we become informed? Wasn't it a happier world when we were perfectly ignorant and knew nothing about all of this? See what kind of trouble you get into when reading this mirror group? Don't you know that folks go away on a regular basis in total despair, knowing for certain it can never be done? (I'm going to go into the online Prozac business next...) But don't despair, Ron. Take heart, because we've been making mirrors that are apparently passable in the amateur astronomy community, so it is certainly doable. Heck, even Bob Goff when testing one of our mirrors said, "You passed". So even though it seems dark out there in the cruel world of optics fabrication, you will be able to test effectively, I'm just certain of it. Have a nice evening; I'm going to close down the shop for the day. :) Carl

Test stand deflection/ color surface map

It was not my intention that we would analyze the "test stand pinch" interferogram in detail, other than to say "test stands pinch mirrors and here is some of the effect". Since Steve ran with it to the extent he did (I wish we had a way to harness Steve's energy...), I'm going to make some further comment and provide a pretty picture that should be easier to digest. In the files section see "***surface profile***". This is a 3-D color surface map of the mirror that is pinched by the test stand. This image will be of interest to those who are following this thread. The line I drew on the interferogram was indeed a simplification as Steve pointed out, because there is likely effect over much more of the mirror created by the test stand. Generally I concur with his observations, as this color profile seems to agree fairly well with his topographical map as well as other analyses of test stand deflection. My only difference is I disagree with his point #1, where he indicated that the deformation I circled is not all due to astigmatism. I think rather that the majority of it is, as I will explain in part, based on the evidence we have here.

Need IMAGE HERE

Looking at the color image, the hill at the bottom of the mirror obviously contains the highest point on the surface (orange-red top). I drew another line on this image, which essentially corresponds, to the line on the original interferogram. Note that the hill is significantly higher than the rest of the mirror, including its counterpart radius at the top directly across, which has only a slight raise in comparison, near the edge (yellow). This hill on the bottom is what is readily seen under the knifedge that I have mentioned before, when doing a graphical flip of a focogram. Based largely on this profile map and what I know about the mirror from our own measurements, I'm of the opinion that the majority of the shift seen in the fringes on the original interferogram where I drew the line is indeed created by test stand pinch. The reason is, the fringe shift as seen on the

interferogram is non-symmetrical with the rest of the mirror, which is corroborated by this surface profile image. In other words, there is no counterpart to the hard fringe shift anywhere else on the mirror on the original interferogram or surface profile map, which mirror we know first hand to be a figure of revolution. We also happen to know first hand that the mirror is in fact very accurate, extremely smooth and zone free, which I will point out additional evidence for below. In greater detail, the mirror on the top half is nothing like the bottom. The fringes on the other side (top of mirror) are essentially straight, which is reflected by the colors being only green and yellow on the top edge, as opposed to going on to orange and red. The way I see it, the fringe shift is indeed the hill created by the test stand pinch. This is not a mathematical evaluation, but rather an observational one (You know how the saying goes, "If it looks like a duck..."). I see no observational evidence to support Steve's point #1 other than the backward tracking of the software removing entire terms and presuming what the fringes might look like without the terms intact. Although I think it moves in the right direction in general, on an absolute level I see that as an imprecise approach. I need to point out here that we don't have an interferogram that was done correctly with the test stand artifacts removed prior to data reduction, with which to compare. So what Steve was left with was to attempt to work backward mathematically by removing entire Zernike terms, and seeing what the software said would be left in the fringes.

I think Steve did very well given what he had to work with, as he certainly got into the ballpark. It was a very creative effort and he got more out of the data than I thought possible. And I think he got fairly close to tracking back to the original mirror, because he came up with a .96 Strehl ratio which is not far from what I estimate the actual quality. Again, I wouldn't take the result (the mathematically generated fringe pattern group) as absolute as I believe the exercise by its nature is only a ballpark guess when it comes to precise measurement. Nevertheless I applaud the work; it was interesting and revealing, and it prompted me to study the fringes and profile map even closer. Thank you, Steve. I do have one more observation about the map, (being as we pulled all this information out) back on topic considering test method agreement. Notice the "mean" area of the mirror. That is, the area that is not the protruding hill at the bottom (orange-red), not the corresponding yellow edge at top, and not the right and left corresponding potato-chip drop-off (blue). The mean area falls within the green. This is the area that is more or less "neutral", or the overall surface of the mirror that is not deformed so much by the test stand. Notice that it makes its way across the bottom above the hill all the way to the edge of the mirror right and left. It makes its way around the middle and over the upper area all the way to the top of the mirror just right and left of the yellow area top center. We have green area in every place that is not affected by test stand deflection.

What my point is, the green area gets from the *center of the mirror to the edge in four places* around the edge of the mirror without being affected by a zone. Given all the deformations surrounding it, it is actually symmetrical in that sense, demonstrating a figure of revolution within the error envelope indicated by the green value on the map. This is confirmation of what we know about the optic from our measurement here in the shop. The green area is the "real mirror". The rest is test stand. Now we can't say *for certain* what the mirror would look like without these uneven pressures unless we had a

properly fabricated interferogram without them. But Steve points out that the test stand creates the bulge at top and bottom, and the falloff on the right and left edges. I generally concur with that evaluation. Now look at the scale on the right, labeled in waves. See that each space has a value of .03? The mean area of the mirror falls within the green. We have this mirror measured at better than 1/20 wave averaged PV spherical aberration. So it appears that even with all the problems with this interferogram, from the best I can tell, there is no disagreement between this interferogram and our knifedge. The mean area very well agrees with our overall PV rating on this mirror. What we need is an interferogram that was done properly by a reputable optical company on a mirror for which we also have knifedge data. Enter "phaseshift10". I haven't begun work yet on that installment, as my schedule is very busy at the moment, but I'll get to it when able. CZ

Steve, (I wish we had a way to harness Steve's energy...) I'm open for requests. :-) We'll keep that in mind. Do you know whether coma was cancelled out of the Zernike terms, before the surface profile was generated? Coma was given a value of .15 wave. Astigmatism has the larger value of .24 wave, which is the largest term in the data reduction, when tilt and defocus were removed. Carl

That's spooky, Dude. I decided to drop that part of the discussion as well (even though I considered several more observational points), and sent my posting with the numbers you requested within the same minute you sent the posting below. How strange. Carl

Carl, I wrote the following, yesterday: Yes, but coma is also asymmetrical, it makes a bulge on once side of the mirror, and a corresponding valley on the other side. In thinking more about this, we probably can't tell from this interferogram whether the coma is due to the test stand deformation or to test alignment. Therefore, I won't have enough data to prove one way or the other that test stand astigmatism on this mirror is balanced top to bottom. I'm fine with dropping this part of the discussion. -- Steve

phaseshift10

We have the knifedge data from our in-house measurements. We also have access to the mirror itself as I re-purchased it. Right now someone is using it for a calibration piece in development of a testing method. The interferometry data side is limited. We have the results in PV and RMS, the removed terms are listed, and we have the calibration bar for the colors in waves. That is all we have. So I don't think detailed analysis in the manner you're hoping will be doable. My analysis is going to be rather simple. We're going to look at spherical aberration, the factor that the knifedge measures. Give me a chance to say what I'm going to say, and then you can have whatever we have on hand and do whatever you wish with it. (Right now I have a lot of work to do.) Carl

Carl, I'm looking forward to what you write about ***phaseshift10***. If you have the raw data available, I would find it interesting to try applying my comparison technique to the interferometer and knife-edge data. It might add to this discussion, and it would help to confirm my methodology. Do you have this data, and are you willing to share it? At a

minimum, I would need: 1. The original knife-edge data or the averaged knife edge data. 2. The Zernike coefficients derived from interferometry. (I would ask for the original interferometry data, but I doubt I have the means to analyze phase shift data with my current programs.) What do you think? -- Steve Koehler koehler@s...

Just for Fun

"Fun"? What's that? And why did you put the name "APO" on a perfectly good reflector? Reminds me of the Olympic athlete (of unknown ethnic origin) who was so pleased with their gold medal they went out and had it bronzed. "Tee-hee" CZ If you scroll to the bottom of this link: http://c3po.cochise.cc.az.us/astro/observatories06.htm You'll see a Scope that has "notation" on it that for some reason drives Refractor Scope owners "Nuts" ;-). The text needs to be updated as this Scope has been operated at 1016X clearly 15 times since where you see it pictured, on Planets and Double Stars - thank you steady skies n Carl Zambuto n Bob Goff. -- Crazy Ed

NYC resident would like a sample view thru Z optics

Harry, I have vague recollection of somebody posting very recently concerning buying a 10" Starmaster, taking one look, and then upgrading. They were suburbia of some large city, might have been NY. Check the thread about addictive nature of premium optics. BTW thank you for posting your request. Such requests are rarely made, but in fact that is what this forum is *really* for, as opposed to all us armchair theorists arguing with each other :) CZ Any one anticipate being at a public star party in the New York City area with a Zambuto equipped scope say in winter or spring. I'm a member of the NYAAA. Currently, I observe with a 12.5" tube DOB from my terrace. I am interested in a better view and certainly in a more portable scope. Harry Lewin

The Ronchi Project

It appears the Ronchi project died of natural causes, in that it apparently lived out its natural life. I believe the list is exhausted and those who have testers in their possession are apparently done with what they're going to do. I guess its time to call in the testers. Those who have them can ship them back to the shop. The shipping address is: Zambuto Optical Company 15341 Vail Cutoff RD Rainier WA 98576 Thanks, all CZ

You're welcome, Brad. You can add to the folder and advise us as is appropriate. My thanks go to all who contributed. I think it went very well. Carl

Carl, I want to thank you for the Ronchi project. I learned a lot, and got my cheapo tester working. I have a few more mirrors I'd like to image and post for your (and others) evaluations sometime in the future. Brad

Testing Methods Agreement

I've spent some time on the third installment of the thread we're working on that is, the agreement of testing methods. A very nice development took place, that is, the actual mirror that represents the interferometric surface profile "***phaseshift10***" has come back home. The individual who is developing a test method is done imaging it and sent it back. What I intend to do is to re-measure it, to find the axes of primary astigmatism on the glass, so that we can do some interesting direct comparisons. As it works out, this will make for a better treatment of the subject, comparing the knifedge with the interferometry. I've got some nice graphics going to support the subject, and hope to make it an interesting presentation. But as in all things, the better it is going to become, the more time must be spent on it. So be patient, and in time I'll begin to present the third segment. Will probably take a couple of weeks given my "other work". CZ

I've been growing increasingly tired of handling the forum for some time. I have some gripes that I could vent, but it's as much about just being tired of doing it and needing a break as it is about my gripes. I've ranted in the past about some of it, for those who are wondering. It's a tough battle sometimes, fighting ignorance combined with attitude problems. Ignorance I can handle, it's the attitudes that sometimes come along with it, that cause undo energy drain. In any case, I've been putting too much energy into the forum, especially on the (very sacred) subject of testing and test methods. What has been difficult is watching when applicable advice goes totally unheeded by some who are studying. It has gotten to the point lately where the correspondence has taken away from my energy and ability to perform my job, in that the work volume is suffering, and I don't find that the result is worth the energy going into the group. So I'm going to take leave of the mirror group for the rest of December, and see how I feel in January. I'll spend the time investing in my job of fabricating optics, and spend some time at my hobby. The forum can go on without ZOC for a while. I would encourage those who wish to, to continue any discussion they see fit. Happy Holidays, everyone. I'm going to take a break. CZ

What is the most gut wrenching sound on earth?

Tom, You drug me out of my cave for THAT? Ok, Ok, I know how it goes. You feel sick about it. The previous posters were all correct. Best chance is it's a non-issue. Yes, this is a common story. People drop stuff on their mirrors rather frequently- wrenches, secondary mirrors, and etc. I think the saving grace here is the magnet is covered with tape. That softened the blow of what would have otherwise certainly created an internal fracture, and probably an actual chip in the surface. There still might be a fracture but even so, internal fractures are typically a non-issue with respect to performance. You have two options- one, forget about it and enjoy your telescope. You can verify this with a star test. If the extra focal rings are uniformly round and you have a clean test, then it is fine. If the test shows non-uniformity to the figure of the extra focal rings, such as if they are not a figure of revolution, then it's worth looking at. Two, send the mirror to me and I'll check it optically. If it appears there is a fracture beneath the rub on the surface I can

strip the coating and do a closer examination, but the optical test will tell me the bottom line. The mirror would have to take one hell of a hit to cause havoc on such a well-annealed piece of glass. If you don't see anything in the star test and if you don't detect any chip of actual glass right there, then the eventual (years from now) recoat will hide the crime. If you see an actual chip, that is, if your fingernail can catch something (maybe worth doing one time to be certain) then there is indeed a fracture, and an optical test-either star, or on the bench, is probably in order. Now let me go back to my winter's nap. CZ

The sound of this: http://www.tomhole.com/images/magnet.jpg (a magnet, 4" in diameter, 1/2" thick wrapped in duct tape) hitting your ZOC mirror from about 4 ft. up. Here's what you get: http://www.tomhole.com/images/zocdamaged.jpg the chip is about 1/2" long and about 3/4" outside the edge of the secondary. The coating is chipped off but I'm not sure if the glass itself is damaged. I would guess it is, but there isn't an obvious chunk out of it. Oh, the reason said magnet fell on said mirror is because said owner is a complete and utter idiot. I have counterweights on the back of the mirror box to balance the OTA with the binocular viewers. Well, when the binocular viewers aren't in, the OTA wants to stand up. I like to store the Starmaster with the OTA horizontal because I want the mirror vertical to keep the dust and whatnot off as I keep the scope in the garage all the time. Well, being the super genius I am, I laid a magnet (the very magnet that ruined my new year) on the UTA to keep the nose down. Well, I wanted to QA my fan install, so I removed the top mirror cover and moved the OTA up towards vertical. What happens? You guessed it. Said magnet falls off of upper assembly and onto my mirror. Are there Darwin awards for ZOC mirror owners? I'm trying to think of an appropriate punishment, but having to look at that ding makes me want to cry, so punishment could only make me feel better. So, Carl, break time is over, let me know what I need to do to get this fixed. Drat! Tom

Carl A Personal Insight

Hi, all I've had a much needed rest. Many factors combined to distract my attention as well as take considerable energy. My wife and myself took the holiday/January break to participate in an opera as chorus members. We did the Marriage of Figaro with operapacifica.org. It was a very nice experience and satisfied my long-neglected music performance "bone", which I kept active the first half of my existence, and have neglected since optics came on board. During Figaro my wife's mother passed away, it was not unexpected and was a long illness. We're now dealing with handling her estate. As a result, January did not see many mirrors ship. All in all it was a good break.

We're getting back into the swing of things. Tonight I have a presentation at the local astronomy club, the Tacoma Astronomical Society for which I put together a slide show. This compilation might be good for uploading to the "shop tour" folder. I intend to do that shortly. There is also still the writing for the third part of the test methods to complete. I've done some work on graphics, and have more to write. I hope to do that in February. Meanwhile I'm not unwilling to answer straightforward, articulated questions that would be of help to amateurs or fellow professionals. What I mean is, for example I

won't entertain a solicitation to go and study a large body of work that somebody has compiled somewhere on the internet, especially when such an individual refuses to answer a professional's carefully thought-out advice. This has happened twice and is a factor in my taking the break that I did.

If someone wants to take the time and spend the energy (such as I do) to make a carefully laid out presentation on the forum as a dedicated posting they are certainly welcome to do so. That is what this place is for. When I become more active again I'm going to stay on track with the subject that I opened, and stay the course with the intended points. I'll talk more in the future and articulate better concerning how I will need to operate without getting sucked into endless numbers of paths and losing valuable time and energy that can be applied to the benefit of the amateur community as a whole. I don't always come to the group every day; in fact I've only taken a weekly glance at best and sometimes not even that. If there is an issue that needs help and I don't respond, someone can shoot me an email if needed. The shop is busy, we're here every day, and all things are continually moving forward. Lots of good stuff happening. CZ

Michael, Someone once mused whether I sing Italian songs while making mirrors. Along with listening to a healthy mix of many genres (I've always been eclectic in nature) the answer is yes. Not so much loud singing as such, but there is a lot of music in the shop from time to time. When absolute concentration is not essential, or at the end of a particularly tough spell when we need to decompress a bit, we put on any one of many kinds of music. A favorite Italian of mine is Giuseppe Satriani (otherwise known as "Joe"), a composer of unusual talent in my estimation. But little stirs my soul more than the Italian of century's prior, Joe Green, also known as Giuseppe Verdi, unless, perhaps, it is Puccini. Okay, Mozart isn't half bad either. We listen to jazz, classical, rock, new age, and yes, sometimes-even "country", but not for terribly long. CZ

Jeff (and all), I've always found this an unusual corner of cyberspace for many reasons. Consider that this group is a collection of professionals with training in theoretical physics, medicine, mathematics, psychology, art, computer engineering, optics, anthropology and a few other fields that I've forgotten (Sorry but its hard to remember what everyone "really" does.). Also consider that we gather to discuss how to make a smooth mirror with a former plumber who happens to sing Figaro. Now I ask you - who needs more help - the Jackson's or the 600 people who follow the discussion on this forum? Just something to think about… My best to all, Michael Gilbreath (You know I'm kidding Carl – I look forward to part three when time permits)…;-)

Mirror cells - some professional literature and ideas for amateurs

Hi, Tom I for one appreciate the caliber of your contributions to this mirror group. Thank you. I'm going to wander on a tangent with your thread, so I ask forgiveness before I do it ("forgive me Father, for I am about to sin"). My (rhetorical) question back to you is how large and thin specifically, do you want to go?

We don't consider 1.5" at 16" as a terribly thin mirror. What you're going to find is given

a reasonable mirror cell such as the Starmaster design for larger mirrors, the problem is not in supporting them well enough, but in FABRICATING them. Take for example a 24" at 1.65" edge thickness. The problem is fabricating it without visible astigmatism. Starmaster can always put a finished mirror of such description in their cell and it works fine. Over time I've watched three professional mirror makers fabricating large thin mirrors struggle with astigmatism and take serious losses in dollars as a result of time and labor spent getting it right, and I'm one of them.

24 inch Thin Blanks

We spent better than a year developing techniques to straighten out the astigmatism in polished 24" thin blanks, then figure them. During the process we defined workable criteria for anneal as well as striae limits, so we're doing better now as far as success rate for a given iteration (lately we're 100%).

Edge Thickness

We have settled on 1.75" edge thickness for our standard fare. We spend about a week on and off with a particular polishing technique to get them perfectly straight (that is after the normal 24 hours of rough polish time) then use slow movement during figuring combined with very high humidity and soft pitch to keep them that way. I'm not worried about the mirror cell. I'm more concerned with getting the mirror fabricated properly in the first place. A 16" at 1.5 by comparison, as you can now see, is a "walk in the park" for support, as well as fabrication. We have successfully fabricated as well as supported 24's as thin as 1.65" at the edge and they meet our specification for performance. That is 50% more diameter with only 10% more thickness as compared to a 16" at 1.5. However initially during fabrication at that thickness I should mention we had as many fabrication failures as successes. I don't think there is any good reason to go thinner than 1.75" on a 24 when it comes to Pyrex. In our professional opinion, the typical non-uniformities in Pyrex as shipped from the fabricator will cause undue grief before you ever get it to the mirror cell.

And if you do fabricate it successfully, I think it has been demonstrated by a professional telescope maker of modest price and design that one- piece mechanical mirror cells can do an adequate job of exploiting the capability of the optic at that thickness ratio. And I assure you, if I thought the mirror cell couldn't do the job, I would do something about it. Yes, there are more exotic techniques out there that advanced amateurs can and should look at for mirror cells. What I'm saying here is, let's get the horse in front of the cart. How many ATM's know how to make a smooth, very accurate paraboloid in the first place? We got a lot of theory these days, a lot of armchair and keyboard experts in ATM-land. But where are the mirror-makers? Show me a 20" fast mirror at 1.6" edge thickness that is smooth as a baby's behind and inside the M-L envelope from center to edge. Then I'll show you a mirror cell. CZ

My $64 question: Can I make whiffletree cells for large/thin mirrors that serve as both axial and lateral support...in other words combine the two functions of axial and lateral

support in one mechanical structure. (The pros choose not to...but can I get away with it? Hey, I've already done it with a 16 inch, 1.5 inch thick mirror...but how big/thin can I go...using a passive system?) I hope this helps feed some ideas, and also answer some questions. Tom Krajci Tashkent, Uzbekistan

True Field of View (TFOV) Limit

Bob, You have opened a hornet's nest. There is a simple answer, but it is not a complete one. Answering this one will take all my correspondence time for the week, but I'll do it, just not all of it this morning. I'll get this thing heated up a bit, and maybe we can get a good fight going to keep things interesting :) The true field of view limit is not constrained by focal ratio. It doesn't matter what your focal ratio is (think about that one a bit). It becomes of question of how much coma you want in your image, as to how far off axis you can view. The first limit is your field stop in the eyepiece. The second limit is the OTA itself. I have a problem in your caveat statement "let's assume the eyepiece and OTA accommodate the mirror perfectly". What does that mean? "Accommodate" in what manner, using what criteria? A paraboloid has a true field of view that is constrained by its reflective coating. Depending on the sag of the mirror, it approaches 180°, provided you're willing to view at a magnification of "one". That bears thinking about as well. So you have to determine what you're willing to tolerate for lowest magnification, then how much coma you can tolerate in your image. Then you call up Uncle AL and ask him to build you an 8" diameter eyepiece that weighs 74 pounds... The question is what criteria do you use to draw the line? That determines your TFOV. CZ

Hi Carl, I'm a proud and happy owner of a 14.5Z Starmaster, and I have a dumb question that's been bugging me for years. I've been afraid to ask it, because I want a simple answer, and I'm afraid that I'll ask it awkwardly and lead the reply off on a tangent. But the time has finally come, so here goes: Is there one solitary factor that determines the widest true field of view a parabolic mirror can see from focus? Yes, I know the eyepiece may impose its own limit, but for purposes of my question, let's assume the eyepiece accommodates the mirror perfectly and the same for an OTA. I would love for the answer to be yes, it's the f/ratio. That makes intuitive sense to me. Needless to say, I expect that will not be the answer. Hoping for the best, and Thanks. Bob Arr PS. anything you can add will be appreciated :-)

Bob, You're obviously a conceptual thinker (my kind-a guy). I understand your question perfectly, and I know what you're asking. My first answer alluded to what you want to understand but was not specific enough to get the point across. I think what you're going to need is a conceptual diagram, either in words or pictures. It will take me some time to figure out how to describe this to you, and then to actually do it. I know you're in no hurry because you've had this question for a long time. Give me some time to put it together for you. Meanwhile, a hint- you've got the mirror hung in space without constraint. Now, take the constraint off of your mind. Get off the optical axis on the source of the light, and use the field of view (space) as a sphere at infinity, which for all optical and observational purposes it indeed is.

Carl What I had in mind was to understand the optics of the primary mirror only, as if it existed hung in outer space all by itself. No mounting, no OTA, no secondary, no eyepiece. I can accept that light "rays" coming from a star that is centered exactly on the primary's extended optical axis can be reflected to a common point, simply because the divergence angle from such immense distances has become infinitesimal. In theory, the rays have still got to be diverging, but they are far beyond the point where it matters. What confounds me is that the mirror also shows other stars in the same field of view. In my 14.5, the field may be several degrees wide. The light rays from those other stars are obviously coming in at an angle as much as a degree or two different from the light from the star on my extended optical axis. Yet they all seem to come to focus. How in the world can the surface of this mirror, which is shaped to focus parallel rays from a source on-axis, simultaneously focus rays from off axis? Well, maybe the answer is that not all of them make it into the light cone. The result may be that those images that are off-axis are simply dimmer. This seems to me to be the case: a parabolic mirror is intended to gather as much light as it can from a source and concentrate it so as to make the image as bright as possible. It's up to the designer to decide just how big to make his field of view. I suppose it could be narrowed to just barely accommodate a star--perhaps .001 arc second. That would hardly be practical, but in theory it would give the brightest image of that star. But an astronomer has got to be able to observe within some reasonable context (field of view), so the designer enlarges the FOV by shallowing the figure. The price he pays is that he gives up some brightness in the center. Carl, you bring up the phenomenon of coma. I don't have an intuitive understanding of coma. Maybe if I did, this whole question would be moot. I know what it looks like in an eyepiece, but as I try to visualize how light is reflected from an off-axis source, my imagination runs out of imagination. I don't quite "get" how the arc image forms. I know it is inherent in parabolic mirrors, and can never be eliminated; it can be minimized with careful workmanship. But the greater the FOV, the worse it becomes out at the edges. The industry long ago settled on standard dimensions--1.25" and 2" eyepieces--and these now compel mirror manufacturers to deliver compatible light cones. I think that within those tolerances, the FOV can be manipulated, but perhaps most mirror manufacturers simply follow an industry FOV guideline. As I said, this seems to me to be the case. I could be wrong :-) Bob Arr

Bob, I need one more qualifier, as I may have misunderstood your question after all. Are we limiting your eyeball to being centered on the optical axis of the mirror? That is, do we have to constrain your eyeball to the center on the optical axis and only tilt its line of sight? CZ

Bob, My question wasn't intended to be that complex. By "optical axis" I meant the focal plane as we normally think of it, where you observe the image typically, through an eyepiece. When you said you pictured a mirror hanging in space, that implies to me that there are no constraints. The focal plane has no imposed border other than the mirror itself reflecting 180° of space back to 180° of space. It gets REALLY distorted as you go off axis, but you can observe all of space with it, just like you can observe your entire bathroom wall behind you through your bathroom mirror. Walk back and forth in front of your bathroom mirror and see the entire back wall as well as the sidewalls. You can see 180° if you go far enough off center. What I didn't know was whether you had

constrained your thinking to keeping your eye in the vicinity of the focal plane on the optical axis, or whether you were in your EVA suit shooting little jets in all directions to move about floating in space to all places with respect to the mirror, at all angles :)

I have observed the moon through an 18" mirror at about 45° off axis from the focal plane. The mirror was lying on the ground, I was standing several feet away, and I was watching the moon at a magnification of one, near the horizon. It was very lovely to look at. It was so nice in fact I photographed it (which didn't turn out so well for various optical reasons) and it was the inspiration for a poster that was made to promote a mirror-making video that was never finished (the production company went out of business near the end). I have uploaded the image for the poster to the photos section. Go take a look it is very pretty. The tree line is an actual view as photographed from our backyard in Rainier, WA. The mirror outline, or skeleton is from the actual photograph of the mirror. The Moon was pasted on, however, as should be quite evident. A graphics artist who is highly talented did the rest.

So you can look through a paraboloid at many angles, right down to almost 90° off axis. However at that angle the distortion won't be small. But if you're constrained to the focal plane area with your eyeball essentially on axis looking about (as if there were a telescope there), then the true field of view is limited by the focal ratio without an eyepiece. So you are right about that. It is simply a matter of the angle from your eyeball to the edge of the mirror, reflecting off into (and back from) space. The objects viewed toward the edge of the mirror will be very dim by comparison to the objects near center of view because very little glass is reflecting them to you. Also the distortion (coma, et al) will be very large, because the light coming from that area, although parallel in its trajectory, is not parallel to the optical axis. It is coming from a different angle. That is what produces the distortion. So my answer to you takes after Einstein's special relativity in a sense. You have to tell me where YOU are, and then I'll tell you what you see. It’s all relative, no?

Chew on that for a while, and then let me know where we are. CZ Gads, Carl, what a devastating question! I don't know! I'm not sure what the alternatives are. I realize that part of the time I am thinking in terms of the focal point, but part of the time I am thinking of the focal plane. (Are you trying to point that out to me?) When I ponder how off-axis images can appear focused, I am obviously contemplating the focal plane, not the central focal point. I realize that if my eyeball is fixed on the mirror's centerline, then only a little bit of the off-axis image can pass through my pupil. The available focal plane is far larger, but I'm only seeing a small circle of it. Now if I allow my eye to "look around" (while keeping my head still), my eyes will overstep the circle that was its limit it when it was fixed on the centerline. Well of course, this will let me see a greater field of view. I'm not sure, but what I think you're asking for is whether my eyeball stays fixed on the centerline, or whether I permit it to look around. In the first case, I effectively restrict the light to a (perhaps) 6° aperture. In the second case, the 6° aperture may wander across a 10° field. I apologize if I have misunderstood your question. If I understood the consequences of the choices, I might be in a better position to help. Could the problem be considered from both possibilities? Bob Arr

Uzbekistan ATMs

Thank you for the perspective, Tom. -Very interesting. I sympathize with you in not having the tools to implement what you wish to be doing. I don't know what I would do if I didn't have my glass to figure. Come back home soon. CZ

In this poverty-ridden, corrupt, police state called Uzbekistan...Uzbek citizens only have the option to study and acquire knowledge...because the physical goods aren't available. And I've met one very smart ATM out here. His brain is full of valuable knowledge. I will keep learning from him, and from books/websites. Back in the US I'll eventually get to mirror making again...I miss it. Thanks again for the reality check. Tom Krajci Tashkent, Uzbekistan

TFOV Limit

Bob wrote: Now when I consider a light cone which is bounced up by a star off- axis, it is obviously tilted as far one way as its star was off-axis the other way. (Your moon picture is a perfect example.) If it's not too far off-axis, some of that light will strike the eyepiece, obliquely. But what will I see if the eyepiece only scoops out a groove from the side of the cone? (How's that for a technical metaphor?) Maybe it is a truncated arc?

Yes, I think that works. Well, that's one possibility (perhaps I flatter myself.) Here's another: For no reason at all, I suddenly thought of the incoming light as a thin- walled cylinder of incoming light, that just catches inside the edge of the mirror. (It's so thin; it's only one photon thick.) It bounces = to focus, no surprise there. But then I think of an identical thin-walled cylinder of light from a far off-axis star. Adjacent photons do NOT strike the mirror at the same radius from its center. (Imagine a flashlight beam striking the pavement at a 45° angle. Its image is greatly elongated. I have to think that the same thing happens to my off-axis light cylinder, even though the angle is only a couple degrees off vertical. Small, but significant.) Since the mirror's surface is continuously curved, adjacent photons bounce off a surface point that has a slightly different slope than their neighbor's. They don't get the same symmetrical bounce as the on-axis cylinder did. For the readership: keep in mind that each “spot” or area of space illuminates the entire mirror.

One star, no matter where it is in the field of view, off-axis or not, is illuminating the entire mirror. That is why the light cone formed by a star off axis can have a curved, elongated shape called coma. If you stop the mirror down, that particular off axis star will show less coma, because as you have pointed out, you have adjacent photons striking the entire surface, and the furthest area of the mirror (which causes the worst distortion by comparison) is no longer reflecting light. You will still see the star, it will be dimmer, and it will have less coma. And I think this might be the result: The cross section of the incoming light cylinder was a circle. The cross section of its reflection is...I don't know, but not circular. Very slightly deformed. Consequently, = it cannot build up a pinpoint image on the focal plane. But whatever image is produced will be a curved one, I expect. Sounds reasonable to me. What's a one-photon thick cylinder of light got to do with

reality? In the = abstract, the entire light cone can be considered as a series of one-photon cylinders, each fitting snugly inside the other, filling the entire incoming light shaft. And whatever process happens to one cylinder happens to all. I think of the whole thing as an infinite number of cylinders of parallel rays the aperture of the optic, coming in from all directions visible to the field of view. Those cylinders' cross-sections are indeed the area of a circle. Of course once they strike that paraboloid off axis, the cylinder's resulting light cone indeed becomes distorted. It appears you have broken the larger cylinder down to the smallest definable item, the photon.

I suppose that's okay for abstract discussion much like my ray traces are for RTA measurement. But those photons are not in truth linear things. They kind of jump around all screwy when we get too close to them. What pleases me about this latter analysis (?) is that it is clear that the= greater the incoming angle, the worse the coma gets. And also, that it is obviously an inherent characteristic of a parabolic (or spherical) mirror reflecting off-axis light, not a defect in manufacturing. I'm certainly relieved to hear that! I worked late on this. Perhaps I should have gone to bed instead: It was fun. CZ

Shop Tour Photos

I'm pleased to announce that finally we have some shop pictures in the photo album. I've uploaded 27 photos with descriptive captions for each. The folder in the photo album is labeled "shop tour". They're in chronological order from first to last, proving a descriptive tour of our process. (This is a non-technical tour designed for the enjoyment of the layperson, so everybody can take part). A nice way to experience the album is to use the slideshow mode. Once the slideshow is loaded, hit the pause button right away after loading the slideshow to pause the sequence, as it moves too fast to read the captions even in "slow" mode. When you're ready to move to the next image, touch the forward button that has two arrows pointing to the right. Enjoy. CZ

Shop Tour

I don't see why not. Where are you coming from? Carl

Good Evening Carl... You have mentioned shop tours several times in the last 12 months or so... I will be visiting my father...82 years of age across the bay from you I believe...Mid June... He would be delighted to visit your shop...as would I... Would this be possible??? Very Best Regards, Preston Engebretson

Pans Under the Turntables

Every optician needs their own personal machinist, and we have used several over the years, but it's always nice when we can find something prefab that meets a need of ours, especially when it does it so eloquently. The pans are nothing more than water-heater drain pans. I got the idea from seeing the pizza-pans on Strasbaugh machines and decided

I could do one-better (the Strasbaugh pans are too shallow). Our grinders have 26" plastic pans under them, and our polishers have various sizes of aluminum. We prime the aluminum ones and overcoat with Plastikote, because cerium likes to eat through aluminum over time. The splashguards can be found at your local builder's supply. Its aluminum flashing that comes in 10-foot long rolls by 6 inches or 8 inches wide. Unroll it, drop it in around the edge of the pan and it automatically expands to the full diameter because it wants to straighten out. Then tape the seam together and you have instant splashguard. For the hole in the center where the shaft comes up through the pan we cut a short piece of large diameter plastic pipe with a tubing cutter and using 100% silicone we glue it down to the pan. It works marvelously. Our 36 inch pans (which we purchased through Grainger) have a layer of 1/4 inch Masonite glued to their bottom to level them out and stiffen them. CZ

Hello Carl... Just a couple of quick questions.... where did you get the pans that are underneath the turntables in the photos, and did you fabricate in- house the metal (?) shields that are surrounding the polishers / figuring machines? Thanks, Bob M.

Slurry Feed Systems

Bob, All of our peristaltic pumps are essentially the same model, from Grainger. I think they would typically be the lower volume models. The difference you're seeing in the photos only depends on where the relay is mounted. Our first system we went through the trouble to mount it in the pump box. It was a pain, but came out nice. The other one is mounted on a bracket on the outside of the box. When we build a system we rip out the electronics from the pump box (although the new designs are different, so be careful how it is done) and we replace the controls with an aftermarket relay that has controllable durations for on and off time. Ours is the 3-minute maximum duration type (MSC catalogue). The relay has a continuous adjustment for off time as well as on time, up to three minutes each. This gives us precise control over how much slurry is deposited, and how often. The tanks are indeed stainless steel batch cans of various sizes (MSC). Mounted on top of the lid, raised up by four spacer bolts is a plastic box with a 120 RPM synchronous motor mounted inside, which drives a stainless shaft into the tank where a fan blade is epoxied on near the bottom.

The tank is continually stirred, with the fan blades scooping the mix upward and stirring the pot. On top of the plastic box is a small 110-volt fan pulling air up through the hole in the bottom of the box. Synchronous motors get very hot if not prodigiously air-cooled. One toggle switch on the side of the box turns the stir motor and fan on. Designing an automatic feed system was an interesting exercise for us. We looked at the Strasbaugh version for $800.00 at that time, which had parts that require replacing as they are not stainless steel, and will simply rot-out. We also found them to be rather noisy. Designing our own system using "cost-no-object" criteria we found that for $450.00 we could build a true state of the art system that has extremely precise feed as well as on and off control, which system has never failed, not one time in all the years we have used them. They are truly superb.

Movies of the System

So now you want movies, eh? They take up a lot of Yahoo space. Just that one slide show at 100K per photo made a significant percentage change in the space left on our site. Perhaps it is time for a shop tour. I have never turned down anyone who asked. We do have secrets, but we don't concern ourselves so much with them, because no one sees them unless they are ready for it, and I have learned that there is no way to steal success. You have to work for it. -Very hard. So if you ever make it over to the left coast stop by and take a tour. We're 1.5 hours drive from Seattle. Carl PS I suppose that once in a while we could film a *short* clip of a requested subject and upload it to the Files section. We could leave one up for awhile, and then replace it later on with something else. What do you want to see?

From the new pictures you have posted in the shop tour folder, I noticed one peristaltic slurry pump that looked like a homemade version, and another one that looked suspiciously like a medical unit. Could you please shed some light on the differences and why one was used over the other? Also, I noticed there seems to be a motorized stirring device on the lid of a "slurry tank" (I am presuming stainless steel -- looks like lab gear) in another photo. Do you get any accumulation of cerium in the bottom of the tank, or does the agitator (presuming there *is* an agitator) provide enough action to keep those areas clean? Again, thanks for the photos ---- can a few mpegs or animated gifs be far behind? Take care, Bob Mazzullo

Server Space for Videos

Sean, Thanks, that's a nice offer. If someone requests a specific item and we deem it worthwhile to spend the time to document it, we just might take you up on the offer. We do have a few short clips on file of machinery that we might use. Let's see what happens. Carl PS you're not a lurker anymore... Carl, I know I'm only a lurker but if space is an issue I can set you up with some web space on one of my servers to post movies or the likes. Wouldn't cost a dime to you or anyone else. Let me know if you're interested in pursuing this. I own a few domains that we could drop the files on. I can get you ftp access as well if you don't want me to drop them up there. Let me know ... Sean http://www.seanwillson.com

VIDEO

No, only lots of individual segments of tape, unedited, and not put together. There is a lot of material, well through polishing, but I don't presently have any of it in my possession. CZ Wait now are there unfinished copies of this video? That sounds interesting. Robert

Mirror Making Video w/Carl

No, I do not have any plans to finish the video at this point. I don't' have possession of any of the footage nor have we communicated with the ex-business owner for 5 years. One thing is for certain. Such a project would not be cost-effective. We started that project before I began the commercial business. Too bad the company went under.

Grinding and polishing was fully shot, but the figuring and finish aspect was not complete. No editing has been done, either. Frankly, I don't know if the tape even still exists. I suppose I ought to call them and find out.

Carl Any plans to finish the video? I think it would definitely be a good video to see. Robert

Painting on the group page

In the two browsers I use, on the left side of the page is a column of choices such as "Home", "Messages", "post", "chat", "files" and etc. Click on "Home", it is at the top. The address, which comes up, should read as below:
http://groups.yahoo.com/group/zambutomirrorgroup/ CZ Excuse me but what is the URL of the Yahoo group home page? Cordially, Erwin Miller
Re: Painting on the group page

Dale Thanks so much for the comment. I debated a long time about putting up a portrait of "yours truly", but it captures so well the sense we possess and believe here, of old-world work ethic, so I gave it a try. I'll leave it to the members as to whether they want that painting up there, and for how long. Comments are welcome at any time, either public or private. Hulan did a beautiful job of capturing a sense that goes on here. The painting was done from a real photograph. The scene depicted was real. The machine has since been revamped and upgraded, but it indeed did exist at one time in that configuration, in that setting (we still apply much of our grit by hand, BTW). Anyone who ever visits the shop will recognize the scene when they're here. If I failed to mention it before, the painting was a gift from the artist. I about fell over when he presented it to me at Table Mountain Star Party. I guess I'll mention here that the image is vastly reduced in size from a digital photo that was taken of the painting. If there is interest in the full size, perhaps I could upload it to the files section. CZ Carl Just wanted to say how much I enjoy having the painting displayed on the Yahoo group home page. It is a pleasant thing to look at. How luck you are to have someone that talented and want to use you as a subject. It does as someone already posted remind me of an Old Masters painting especially in his use of light. Dale Eason

By request I've uploaded an 188K-jpeg image of the home page portrait photo to the files section. Look for "Zambuto Oil Portrait.jpg". The smaller version on the home page had its levels auto-adjusted by Photoshop to make it much more contrast and visible on both platforms, and because of its smaller size. It was not a small adjustment. The larger image in the files section is much more true to the original digital photo. I warmed it up a bit by adding some cyan overall, and upped the brightness and contrast by about 10%, because overall it was a bit dull and green, probably because it was photographed under fluorescent lighting. Generally, the painting does look quite old-world, as it is not a bright, contrasty work. The image in the files section does appear much more like the original. CZ
Re: Cold and moldy Northwest (was: Home page oil portrait uploaded)

Shop Humidity

Ed, I have to admit, sometimes in our lives we seem to stumble into the things we need in order to go where destiny seems to call us. At 9% humidity our optics would be disasters. We now keep the shop about 70% relative humidity at all times, which has helped tremendously by the cool, damp weather in the Northwest. This place is a mirror maker's paradise, but not so hot for observing. Suits me, of course, because I spend most of my observing time in a dark room looking at shadows. As I look back and think about where I moved to 12 years ago (our current residence), I have to admit there is no way I could have planned or calculated this whole thing. No way. Although one half of me is a scientist, the other half is a certainly philosopher. We were just discussing in the shop last week that we do in fact absolutely believe in some kind of destiny. We may not know for certain what drives it, but there are too many coincidences in the thread that seems to define our existence. We only *think* we're in control. That's my philosophy utterance for the month. Hey, BTW can I introduce you to the group via a photo I took when at your place, of yourself and your lovely wife in the kitchen? I seem to recall a T-shirt that said something about Alcohol, Tobacco and Firearms... CZ Carl, You know better than that! You've spent WAY too much time in the Wet and Cold Northwest. You're just turning Moldy ;-). Crazy Ed, where it's now 9% Relative Humidity.

When testing mirrors, we use empirical evidence, which tells us of a result. We may not know precisely how that result took place given all the variables, but it is in the end, the result that counts. We do the best we can to control all the variables to the best of our ability, which is synonymous with your keeping your hands on the controls whenever possible. I would say their fate was determined by the outcome, no matter who finally took control of the plane. You had two variables involved, including one that was designed to insure the other. Teachers/instructors are a good thing. CZ

Maybe these Iranian pilots were 'fated' to refuse to control the aircraft, and maybe the instructor pilot was 'fated' to do it for them. (How would you test for this...to prove/deny the existence of free will or fate? I don’t know, but I'll keep my hands 'on the controls' whenever possible. ;-) Tom Krajci Tashkent, Uzbekistan

Erwin Miller wrote: But from the many testimonials that frequent this group Carl is definitely in complete control of the Pyrex that lies before him and awaits his fastidious craftsmanship. I appreciate your sentiments, but let's amend the control statement to say *most* of the time. Today we sent two 14.5's back to polish. In the search for ever-smoother surfaces, this time by using very soft pitch, we got into trouble with astigmatism. It appears the contact was so good that the mirror was wiped almost dry during rough parabolizing. That took us back to the place to where we were before we used humidifiers to keep humidity up above 60%. "Two steps forward and one step back". CZ

Humidifiers

For those in dry climates, humidifiers work well, especially when confined to small

spaces. I wouldn't ever want to try to work in the same room as a pottery kiln when it was going, as the temperature fluctuation would be terrible, as well as the humidity very low because of the heat. In the summertime and warmer weather we use evaporative humidifiers, otherwise known as swamp coolers. They do a dandy job of humidifying the air and cooling it at the same time. There are several kinds, and I don't mean the kind that mount in the window. Sizes range from tabletop to console-type on wheels. In the cold weather, if we need humidity (and we usually do to counteract the room heater) we will often use a heated-type. There are kinds that actually boil water with an immersed element in a small container. They emit warm, moist air and work quite well, except that they need cleaning of the scale that builds up on the heating element. Also in a pinch, a simple a pan of water on a hotplate does the job, too. Not so friendly in the summer, but in the winter they're okay. As we approach warm weather this season, we have three humidifiers running all of them are evaporative type. We need to dump water into the air at least as fast as the air conditioner takes it out and dumps it back outside. We constantly monitor the humidity level with hygrometers in the shop, and adjust the setting on the humidifiers as well as the AC to keep it in balance. The ideal optical shop would be a basement, or underground shop that is often rather damp, nice and cool, and stable temperature. That will be our next shop if there ever is another one. CZ

I don't think I will ever do another mirror since we moved up here to the high desert. I did two mirrors "down below" in the Los Angeles basin and if you pick your season and time there is no problems with humidity or temperature of the workroom. (Did my first one in my old kitchen, and the second in the garage) But here the humidity is always low. (OK so it is 102 degrees outside, but it is a "dry heat".) I don't know how long a wet would last out here as when I turn on the sprinklers during the day there are spots that are not wet even when I see water falling there. Down in the basin we used to get what we called "June Gloom" and often with light mists or even light rain. But, here I would think I would have to put one of those misters in the garage and I know my wife would not like a mister running around her pottery kiln or copy machine. 8-inch f/6 Pyrex DOB home ground polished and figured.

Roof Top Sprinkler

Now they know everything. I'm doomed. More seriously, that's when the temp goes above 80°, which is usually July-August. It’s as simple as the air conditioning wall unit can't keep up. Cooling the roof makes a serious dent in the radiant nature of the heat coming from above. We can feel it right away as soon as the roof is wetted, and that's with R-30 in the attic. Also, interestingly the sprinkler on the roof adds to the humidity surrounding the house, and it also cools the temp slightly. It would -really- be nice to have about a 2,000 sq. ft. daylight basement for an optical shop... CZ

Carl, I hope I'm not giving away any trade secrets, but don't forget the rooftop sprinkler. Last July when I visited your shop you had a sprinkler system spraying water on the roof of your shop. The PNW has certainly been cold and gray the last few days, but the Clear Sky Clock suggests maybe I can take the 14.5" out tonight. John R Gig Harbor WA

Crazy Ed and his wife Carol

As threatened, I've uploaded a picture to the files section of Crazy Ed and his wife Carol. This photo was taken in November a couple years back while I was on a trip to Tucson. Ed and Carol put us up for the night and fed us a wonderful home cooked meal. The next morning, after arming himself profusely from his gun safe he took me on a walking tour of his property (I'm not sure whether I felt very safe, however. One can get rather nervous out in the middle of the desert with a gunslinger that calls himself "Crazy"). Ed was a mainstay in the ATM community for telescope parts, for many years. One of his customers was Starmaster, for Teflon and Ebony Star custom made for the scopes. Ed enjoys very dark, pristine AZ skies through his refractors, reflectors, and binoculars. Some time back he closed CEO, and now enjoys retirement in a very beautiful and peaceful setting. Look in the files section for "CrazyEd.jpg". CZ

Turned Down Edge (TDE)

Well Bob, it’s not so easy for me. You may not realize what you're asking. Understand there are commercial mirrors out there made by reputable professionals that have TDE problems. If it were easy to deal with, there would be none. There is no such thing as a short (a MB or so) video clip demonstrating how to eliminate TDE. I'll let someone else attempt that one, because there are too many variables (TOO many). Plus there are several methods for fabricating a mirror, and with ours it’s just not so simple. Now if someone else wishes to describe to you their techniques and rules of thumb, that suits me fine, I wish they would. However from our perspective you may as well be asking how to blueprint an engine in one easy lesson. Such a subject in the manner in which our methodology would address it requires more on the order of a full apprenticeship.

The reason is our entire process is designed in such a manner that TDE is just naturally eliminated. I doubt I will be teaching the whole of machine figuring on the mirror group, and that is what it would require for the information to come from here. In short, the finished product without the turned edge is a result of our entire process as it is normally accomplished. Otherwise, I don't have a lot to say about it. It just isn't all that simple, as I see it. My intention in offering a short clip was to do something like shoot 20 seconds of a polishing machine in action so you could see the typical movement, or something like that. I'm sorry but I won't be teaching machine figuring in any large sense on the mirror group. Its too large a subject, and it I ever did, it would be in a more permanent media, as has been suggested by one very wise author I happen to know. So in large part you're going to have to just dive in and play with it. I can provide suggestions for *specific* questions. At the same time, probably the majority of learning the art of mirror making is to try stuff and screw it up. One needs to make many mistakes in order to master the process (I think we've been here before, no?). Even with a teacher on board, in order to become accomplished you have to get TDE then experiment and learn how to eradicate it. If someone thinks a teacher being on board can solve all the issues, just ask my apprentices :) Carl

Hello Carl.... That's an easy one to answer, based on my level of experience so far.... a

short clip on what steps ZOC takes to correct / avoid TDE during polishing and /or figuring when done by machine. I believe a visual on that subject would be very informative - provided of course the result doesn't go into the "proprietary zone". Thank you for the notes about the slurry feed system. Bob Mazzullo

Bob M. wrote: A part of the reason I asked about how to cure TDE was to gauge its difficulty by your reaction, and your response. If you had said something along the lines of "Do this and this, with this lap size and for this much overhang (hangover?) Etc. etc. etc." then I would have viewed the printed matter with more weight. But since the reality (your experience) has little semblance to what I am reading, I will make my own way here, as I have so far. View the printed matter with weight. If somebody wrote it in a book or journal it is because it worked. The problem arises when variables that are not mentioned are different in your circumstance than where they were working for the author. Those parameters can be used as a basic guideline. Then you can change other surrounding variables, one at a time as needed until you get the result you're after. It was not my intention to revisit our prior discussions. The last thing I expected was to discover I had asked for the "grail" of mirror making. Oops. I also thought that if the pros distributed finished product with TDE, it was because they didn't give a damn about the finished result; mediocre was fine, as long as it got to market. Not because it was difficult to achieve. I didn't say that wasn't true, because there is indeed more than one standard for a finished product in this industry. What I mean to express is that quality takes more work. One thing to go in a rapid production setting is the edge.

Let me say it different: If it were easy to get a good edge, all edges would be good, no matter what the standard. It appears that mirror making, while made up of different separate steps, is also made up of different interdependent steps; that were a big surprise for me, anyway. Yes. What is so is that to get a premium result all factors that apply must be true simultaneously. It is like a chain dependent on its weakest link. You can do a superb job until the last figuring step when the temperature in the work area drops, the lap hardens up and the tool flexes in the temperature drop, and you turn your edge in about 30 seconds. I really envisioned about a 30 second clip showing essentially "to avoid TDE, set up your machine like this", and show the motion of turntable, etc., etc., and that would be that. To a point such things can be done. But do you know how many different machine designs and fabrication methods there are??? I got to have at least A FEW specific parameters. I'm only willing to work so hard, here. I'll ask formally at this point for everybody reading that the participant not ask me general questions, but rather, that they lay out their scenario (indicating they are indeed working up a good sweat in their effort) in as much detail as possible, then that they ask one specific question.

I'll give everyone an example: "Carl, I'm working on a 6" F/8 with a Pourstone tool with 1/4" of Gugolz #64 pitch. I have the tool resting on its back with mirror on top. The worktable is plywood and I have a foam pad under the mirror with three cleats holding the tool. No matter what stroke I use, I can't get rid of my turned edge. Any ideas on what I could check and do different?" Then I will have an answer. I will cover three or four things. Then you'll get back to me and say which of those things are handled, and which are not. Then it is probable that in a day or two we can solve the problem.

For the readership (I mean everyone, and not you, Bob) this is not a "one-man show". When I took sabbatical the group just about molded away and that's too bad, but that's how it is. If you want entertainment, there are over 100 channels on your local cable. If you want to think and learn and grow in the area of telescopes and optics, and if this particular forum has value to you, then join us and come to work.

I had actually come up with a contraption to avoid TDE entirely. On paper, it works great, cheap, and easy to do, and pretty odd. Reality will, no doubt, show me something different. Yes, you wrote to me about it and its clever, and in concept is not new. It was well conceived. Bob, I'm pleased to see your tenacity in considering and working at something that too few people do anymore. It's easier now to just get out a credit card. Cheers, CZ

Hi, Dale working by hand. 16" 1 inch thick plate ...Ouch! Tried my F/5 with a Pourstone tool with 1/2" of Gugolz #64. Then tried 1/2" of Gugolz #55. Got a better sphere with #55. Work area temp 65 deg. Basement in Minnesota winter with humidity at 40%. Worktable sealed particleboard braced with 1 x 2's. Don't think it is flexing anymore but it was until braced. Table covered with 1 layer of rubber drawer liner. Working mirror on bottom no cleats. Tool weighs about 20 lbs. and is 1" thick. I tend to get the last inch turned up then the last 1/8 turned down. Can't get rid of the turned up without getting more turned down. The bottom line is I can get good control of the center and out to the 70% with various strokes and tools. But I have not been able to get control of the last 2 inches. I have been thinking that it could be caused by:
1. The mirror is rocking because of no cleats.
2. The table is not flat enough
3. The tool is flexing
4. Some other causes
I got to admit, Dale, you're a brave man. I would probably never try a 16" at 1" thick, but I'll do what I can to help you. My first reaction is the problem is flexure combined with contact. Flexure causes contact problems. The evidence for this is that you're getting conflicting messages in the outer zones, that is, the turned up then turned down. It is very important in mirror making that the glass be able to assume its natural shape. Thin glass becomes exponentially harder to affect this.

My thought in this case is to get your polish done, then work on the figure. That is, the mirror's edge will probably polish out faster and better with the tool on top. Get that done, and then begin to work with the figure problems. I'm not a specialist in working large 1" thick mirrors by hand, but given my experience I would take an approach like this:
1. If the mirror is thin and easy to warp, then the tool should be more stable. In this case I would not limit the tool to 1" thick. One is not able to "save the other", as it were. You need some stable reference that will be able to keep the other piece in line, to shape it properly. If it's not the glass, then it has to be the tool. Myself, I would want a full diameter 2.5" thick tool for example, for finish polish and rough parabolizing. I would keep the thinner one, but also pour a thicker one to see if I can get things more stable. As

long as the workroom temp stays stable, a lighter material such as Hydrocal is acceptable.
2. Because the mirror is so thin, my choice for figure preparation is to have the glass on top. The very stable thicker tool will standardize spherical in its shape and give the mirror something uniform to work with. It will require long strokes to remove the TUE. Good contact and long strokes will do this. And interestingly enough, the TDE at the edge will disappear at the same time. Good technique always removes TDE. You will in essence begin figuring with the longer strokes. Go center over center, longer and longer, to try to get rid of the TUE and correct the outer zones. Keep the facets well trimmed so the pitch can flow, keep the contact good by pressing often. You see, the way you're going to solve your problem is to parabolize the mirror. Is that not what you do when you correct the outer zones? The mirror should begin to come together and look more behaved during this work. Your TDE will disappear and if your contact is good the outer zones will begin to smoothly correct. Then you finish figuring, MOT; or, TOT if you plan to finish with sub diameter laps. And remember, during figuring, keep very good contact by pressing often. Oh, and you will need to spread the pressing weight out because of how thin the (G-D) glass is. For pressing technique MOT I would put one or two layers of carpet padding over the glass, then a plywood disk the size of the mirror to distribute it evenly, then the weight.
3. When doing this MOT work, your hands need to be near the center of the glass. It is too thin to go pushing around on the edges, and that's not good technique anyway. The most common reason for TDE in hand polishing is bad stroke technique. Workers will push the glass by the edges, usually toward the side nearest to them, and that turns the edge. The glass has to believe that the pressure is coming from the center. I used to "spit" on my hands to get the right moisture level to stick to the glass in the center without grabbing the edge. Or use some gloves that have sticktion to them, or the spray that basketball players use, etc. I can remove TDE by hand right away with the technique, so much so that I'll wind up with a turned-up outer edge. In the article by Bob Kestner on large, thin mirror making he would polish on a shag carpet. That's also a good technique for floating the glass, especially when it’s on the bottom. If I recall, the article probably resides on Mel's website. I would read it over, if you haven't. As long as your basement temperature is stable, I think you will find significant improvement with the above items. And next time, spend a few hundred bucks and buy a thicker blank... :) CZ

Dale, You've been through a lot. I offer some perspective on two points:
1. You don't need a perfect sphere to begin figuring. You only need a figure of revolution, with a *reasonable* but not perfect edge (good MOT technique will eliminate it during figuring), and it doesn't really matter whether it is prolate or oblate. It just doesn't matter. What matters is that it is free of astigmatism and that you can get from where you're at to the desired parabola. That is where experience comes in-
2. A hole in the middle after 5 minutes is not a hole in the middle. It’s a slight dent that begins to move toward your parabola. Yes, it looks ugly, but is likely harmless at that state. It is essentially meaningless unless it is deeper than (or close to) the distance between the center and edge that you want in the finished piece. This is where a wavefront profile comes in.

We figure off the wavefront profile. When you zero out the edge that tells you how much

glass has to be removed toward the center. (Most of today's software programs probably can't do this- they are not necessarily designed for actually fabricating glass). On our worksheet we change the COC constant until the edge is at zero, then look at the wavefront profile. This tells us exactly how much glass needs to be removed, and where.

I bet if you had measured the mirror with the hole in the middle, then zeroed out the edge you would see a hill that is still very tall, maybe 100 or 150 micro inches. Using a full size lap with good contact such holes will smooth out. And yes, they can be mitigated with a smaller lap doing "W" strokes as well that is true.

The key for not turning the edge with your sub diameters:
1. Keep the pressure centered on the lap (use one damp hand if possible with your palm at center). You want it to think there is a machine driving it from a pin in the center.
2. Don't overhang more than 25% the diameter of the tool. It sounds as if you were in a decent place with your existing tool. Perhaps it is doable once again. But if you want more stability a thicker tool never hurts. I'm off to go back to work on our (relatively) thick glass :) CZ PS it just occurred to me that after all that prep work the hole was likely caused by the thin tool not being stable enough. A thicker tool would probably be safer. Be sure your shop temp is STABLE while polishing and figuring, as the tool is a different substrate than plate glass, with a different expansion coefficient.

Thanks Carl for the info. I will give your advice a try. To further clarify my state. Mirror has been polished out for some time. At one time I had it to a very good sphere (after many edge problems) except for a slightly turned up edge. I can measure very fine detail with my computerized Foucault system. The edge was only turned up 20 nm for about the last 1/2" at one time. I could not see it turned in the 150 lpi Ronchi test. That gave it a figure of merit with respect to a sphere of 6 RMS and a Strehl of .990. At that time I started to figure it. I thought it might turn down as I figured it using full size tool. I didn't do that right and after 5 minutes got a hole in the center and wanted to correct that before I continued. To fix it I switched to an 8" lap and tried to reduce the edge. I over controlled as beginners do and turned the edge. I did some other bad stuff and decided to head back to the sphere. That is when I started having edge control problems again. You are right I had forgotten to go back and look at my notes to see how I corrected the TUE problem the first time. I did use MOT. The reason for the 1" blank is not for money saving but for weight. We will see but I'm trying for an ultra light scope of about 50 lbs. I have read Mel’s info many times as well as others. I'm one of the contributors to Mel’s code. Instead of carpet I had used astro turf at one time. But the far edged of the mirror would lift as I pulled the tool back toward me. That didn't seem like a good thing so I changed to the thin rubber pad. I'm thinking that even with the thin pad the mirror wants to tilt a little at the end of each stroke. I'm going to try to measure it to see if it is happening. I have machinist tools. That may also be why I had better control with Mirror on top. I will try your advice. Dale Eason

Robert wrote: I have read all your replies on this and thank you for the responses. I am going to be attempting the same thing as Dale a 16" x 1" plate glass mirror. My question is where do you draw the line at too thin?

There is no line. It’s a matter of experience and what your criteria are, and what kind of optical quality you need. I know this is going to be a challenge. I appreciate the ideas of using a full thickness tool. Currently I am working on a 10" x 3/4" mirror. I don’t know how that will turn out yet. I will see how that goes before I move to the 16". Good idea. What do you see is the limitation in thin mirror making? The substrate. To make uniform optics the glass wants to be uniform in its behavior. So optical grade glass is preferred for going very thin. Is the mirror cell support more advanced than the amateur’s ability to fabricate? Generally I would say so, DEPENDING on what criteria for quality we're talking about. I recall an S&T article about a lightweight 16 with 1/3 wave of astigmatism in the mirror (?). Sorry, that doesn’t wash in my book. Or is it the mirror cell supports are not adequate to the amateurs ability to fabricate thin mirrors? I see a lot of information and bandwidth on supporting mirrors with 27-point cells. I was just wondering if there is a capability to actually fabricate a mirror that is thin enough to need such a support? Larger mirrors need more supports. I hope I didn’t exceed my quota of question marks. Nope. Its just sometimes I have more time to respond than others. Today is a short day. CZ

TEST METHOD AGREEMENT

Steve, Dan, mirror group readership, Steve's finding that the mirror has asymmetric turned up edge is most likely correct. Let me bring your attention to the archived image "***phaseshift10***" in the photos section/bench images folder. The red is up. See how narrow the red band can be. This is not due to .03 inches of offset of the paraboloid on the mirror, rather it is straightforward two-foci astigmatism, ending in a turned up edge. The reason is most likely the thickness of the glass. Keep in mind both Jon's mirror and ***phaseshift10*** are only one inch thick, a 10:1 ratio using Pyrex. When thinner glass such as these is used, astigmatism begins to come into play from the nature of the glass itself. Being non-optical grade glass, it will have a tendency to flex asymmetrically during fabrication more than thicker glass does, simply because it can. The axis that flexes downward during temperature shift will not get the same treatment, and so will result in a turned up edge. This is a tradeoff we encounter when using thinner glass. In agreement with Dan's assumption on it not affecting the image, keep in mind that the highest peak and the lowest valley from the mean on Phaseshift10 is no more than plus or minus 1/28 on the surface, or plus and minus 1/14 at the wavefront. That means of course that the mirror is "1/7 wavefront PV" in two dimensions, meaning, over the entire two-dimensional surface. I'll expand here for a moment in keeping with my thread on test method agreement-

The 1/7-wavefront number when used with interferometry represents all 36 Zernike coefficients, (36 different aberrations that are measured, combined). For the readership's information, this is not the same as "spherical aberration", or possibly more precisely "averaged spherical aberration", which is what the knifedge measures. I'll note here that the spherical aberration coefficient on ***phaseshift10*** is about 1/25 wave, as I will show in my next segment on the thread of test method agreement. That number is in agreement with the Foucault measurement we made in the shop. I'll mention once again that

phaseshift10 has an RMS of 1/45, which translates a Strehl ratio of .98. This would be indistinguishable from a perfect mirror in-focus at the eyepiece, especially at up through 50x per inch.

To have such a high caliber test done on the mirror (***phaseshift10***) measuring so many points was some good information for us. Standard-fringe interferometry does not do quite as well with edge information, although one can certainly see the turns in the fringes. But it doesn't map as thoroughly as phase shifting and this particular software (WYKO). Once we saw this information we made a decision to change our small mirror thickness ratio to 9:1 as opposed to 10:1. This is a compromise; to help to mitigate the raised edge/astigmatism effects we see in the test mirror and Jon's mirror, and at the same time not thicken the mirror substantially. We didn't "have" to do this, as we know well that we're making mirrors that fulfill our guarantee and then some, but rather we did this to find the best possible balance between telescope design, weight and mirror cooling, and optical quality.

Now you understand the reason the higher caliber industrial shops demand to work with low-expansion substrates such as Zerodur or Quartz. Asymmetric anomalies during fabrication are reduced with optical-grade materials such as those. So the likelihood is that Steve is on track with his work. It appears these mirrors can have turned up edges that are not figures of revolution. CZ

Turned Up Edge

At any rate, this [sector of TUE] sounds reasonable to me. What is actually more interesting to me is how it got that way. I am certain that it was not the result of an error in polishing and figuring, since there is not much probability of such a localized aberration occurring with precision machine figuring alone, and turned up edges are normally figures of revolution and the result of repeated wear with a certain set of motions, forces, temperature and humidity. What could be is that there may have been a small volume of inhomogeneity in the glass in this region that during figuring and upon inspection at room temperature, escaped detection. Only when the mirror is in the process of cooling might this small region of inhomogeneity affect the small segment of edge zone enough to be noticeable in a star test. I have no idea, and I'm not sure we will ever find out. Because the error is so close to the edge, it seems unlikely to be due to the Delrin triangles glued to the back of the mirror.

I have another thought. Could it be that the mirror's optical center is not aligned with the physical center, and that the whole mirror had a slight TUE (Carl mentioned his process often produces a slight TUE) that was only taken off of 3/4 of the mirror when the bevel was made? I have seen some other evidence in some of my runs that show a decentering of the mirror surface features in the direction of the TUE. I will have to look closer for evidence of this as I complete my analysis. Given the small area of the anomaly, it seems very unlikely to have any detrimental impact on in-focus images--which doesn't diminish its value as a case study for what you are attempting to do. I'm not sure I agree with this conclusion, yet. Several of Jon's star test images are misshapen. This is especially noticeable near and at focus. The focused stars are triangular. It could be that the sector of TUE in the wavefront is the primary contributor to this, rather than the slight trefoil. I

don't yet know. -- Steve Koehler koehler@s...

Jupiter webcam image/"Calling Mike Harvey"

Hey, Mike so nice of you to show your face! So where's my observation report you promised me? We here at the Zambuto mirror group are growing TERRIBLY weary of theoretical discussions that are only remotely related to what is important about amateur astronomy. We need a breath of fresh air from a personality who lives in the finest place in the continental US to observe and who just HAPPENS to have one of the rare, largest aperture mirrors we make available. To date I have seen no comprehensive observing comparisons, notes, or reports with such an optic from anywhere. We're just dying to know if a 24" is a true planetary mirror, and how it does do on deep sky, and what you have compared it with to date. Have you set up next to any 30's yet? (Any yard scopes, perhaps?). Enquiring minds want to know, and you're hogging the eyepiece over there :) So.... if you want a chance to toot your horn, I'm giving it to you! There. Now you're on the spot. "Speech! Speech! Speech!" CZ

Thanks. That was a very nice report with a wonderful wealth of detail. At the Winter Star Party last month, Attilla Danko and I spent several hours with my 24" Zambuto, observing what appeared to be a couple of large barges that were developing. We both commented that they appeared so 'bluish'. Now, of course, it seems certain that we were seeing the genesis of the blue streak (whatever it is). Mike Harvey

Mike, Your report is graciously received. Thank you. You have answered an important question, and that is one of aperture and "sharpness". Stated otherwise, "Is a larger aperture telescope suitable for planetary observing?" You're beginning to confirm my suspicions. The story goes like this: As we all know, amateur astronomy, historically has said that smaller, long focus telescopes were the planetary instruments. Then along came John Hall who demonstrated for the first time otherwise (did I ever tell the story of when I looked through my first Pegasus mirror? -let me know and I'll recount if it hasn't been done). He showed Rick Singmaster and the community as a whole that large, fast mirrors are planet killers. Okay, I'll confess. They're not suspicions. I know for fact that larger aperture has no problem with the planets. But what I know and what the amateur industry at large knows can sometimes be two different things. Just go to a competitors forum to see how that works :) So we need guys like Mike to tell us how it is, because I'm not paying him anything. Back to the subject, I recall a night at Table Mountain Star Party some years ago when I took delivery of my first large aperture telescope, a Starmaster 16". The planets were up that night and we had nice views of Saturn at about 425x. I was impressed and enjoying it. But close by was another telescope with a 22" Zambuto (refigure) mirror in it. So I had a look through that telescope and the rest of the night my 16" was lonely. We spent the night looking at Saturn and deep space objects through the 22". The view was no less sharp, even though the seeing held the image at just over 400x. The resolution was higher, and the saturation and 3-dimensional look more acute. There was no reason to be using the 16 when I could enjoy a planet night through a 22.

Another story I may have told before- When I first came on board commercially the rule

of thumb at Starmaster telescopes was that 16" was the size where the "breaking point" took place when it comes to planet observing. It was based on average conditions, where larger aperture just didn't do as well on most of the nights. If you wanted a telescope that performed best on the planets on more of the nights you would buy a 16 as a largest aperture. Then we did our first 18" mirror for Starmaster. At that point the rule of thumb changed to 18, because during field testing Rick was seeing six stars in the Trap on any night regardless of seeing conditions. Some time later on we did our first 20". At that time the rule of thumb changed to 20.... and so on, and you get the gist of the story. So, what we're trying to establish here is whether a 24" is a suitable planetary scope, and whether is shows more or less detail than a smaller aperture in varying seeing conditions. Mike's report seems to indicate that it looks promising. We look forward to more reports in the future. And Mike, thank you for being such a good sport. I appreciate it. Carl

Hi Carl... Trust me, I've WANT to give you that in-depth report! A nasty combination of work, family crises and lousy weather has conspired to keep my observing time way down. I had hoped to get 'caught up' at the Winter Star Party but we had spotty weather there as well and only sporadic moments of really good seeing. Even without the outstanding seeing we normally expect in these parts I CAN tell you that the 24" is, indeed, a planet killer! I'm afraid that, when we finally DO get one of those sub-arc-second nights I may faint and fall off the ladder. As it is I've disturbed a number of nearby observers with sudden exclamations of "holy sh**" or wordless shouts (even moans of ecstasy)! Perhaps the greatest testament to this scope's performance is that I have not yet viewed through another scope that has made me wish that I had IT instead (and I've been known to be notoriously fickle!). The Jovian 'barges' that I referenced observing (and that have, apparently, become the new 'blue streak') were not only easily detected in the 24" but were obviously blue in color. While they were also seen in smaller scopes nearby, the coloring was not as noticeable or was totally absent. The 24" also cleanly showed that festoon-like tendrils were dropping down out of the 'barges' into the zone between the N and S EQ belts. This was only 'hinted' at in the other scopes. The amount of detail visible on the Jovian disc during moments of really good seeing was simply overwhelming. Saturn showed 'blush' marks scattered over its disc and I was simply unable to accurately count the number of tonal shadings associated with latitude changes between the equator and the poles. It was like a myriad of lesser 'belts' of the most delicate pastels and earth tones. Marvelous!

Having previously owned another 24" Starmaster without the CZ mirror I can tell you that I never observed this amount of subtle detail before. While the previous mirror was not BAD in any respect, it simply was not the equal of the new mirror. I can readily see an improvement in contrast and stellar images are more intense. Several 18" and 20" owners who've used this scope have remarked that globular clusters are noticeably 'sharper' looking. I find this interesting as, if the difference were one of a larger aperture only, they would be more likely to say that the globulars looked 'brighter'. For two nights I was set up just a few feet away from Vic Menard's outstanding 22". I must confess that, in the past, I avoided looking through Vic's scope because his images (planetary and deep sky) were consistently superior to my old 24". I'm happy to report that, after running back and forth from his eyepieces to mine numerous times, this is NOT the case with the NEW

24! This is good in several ways, not the least of which is that I no longer lie awake nights trying to figure out how to steal Vic's scope! :) I'm hoping to get out to a dark site next weekend and will definitely be at Chiefland for the Spring Event in April. More reports to come! Mike Harvey

Zambuto vs. Kennedy mirrors

Hello, Richard I'm interested in replying to your query, however I will have to carefully temper my comment. For me to say anything about another commercial mirror maker is touchy. So let me go about it like this: First, I'm delighted to see another mirror maker enter the fray who markets themselves as premium optics suppliers. I'll say why in a moment. Regarding reputation, I have not seen Kennedy product to date, and have not yet read any field report on his mirrors. You might do a search on the major forums, such as Talking Telescopes at Yahoo, Big Dobs, Sciastro amateur, and such. Then of course you could follow the links provided by the manufacturer as well, that is, talk directly with any customers they have to date. Along with that, the best thing to do is to actually use the telescope/mirror.

If I were going to make a multi-thousand dollar purchase on an optic from a newer mirror maker without a time-tested reputation as yet, I would want to actually see how it performs. I would probably invest in at least one trip to wherever I needed to go, to spend a night or several at a major star party and see the Kennedy mirror. Now I don't know what your experience or expertise is but to take it one step better, I would spend the effort to get someone with a larger aperture Zambuto to the same site.

Fortunately there are now over 1,000 Zambuto mirrors in circulation (we haven't counted the precise number as yet) so the chances of having one or many at a major star party are actually quite good. If you really want to see how it goes, you get the two side by side in the same seeing conditions at the same magnification (or power per inch, whichever applies) on the same object with the same eyepieces. Then you get to see where it is. If I were the new mirror maker I would be begging people to put our product side by side to prove performance. The fact is, we still strongly encourage that, because that is the only way to know truly what the product is, and that is side by side at the same time.

And a side note in general when shopping, it matters not what anyone claims for a Strehl ratio, because it has been proven beyond any doubt that historically such information is purposely misused and misrepresented, which ruins it for everybody. I would forget about numbers and paperwork (that includes ours) and get to the field test at the eyepiece. That is where the rubber meets the road. Now, about why I'm delighted to see another mirror maker taking a shot at premium performance- I'm of the opinion that if we had suppliers in the game who were actually making mirrors at the level we make them, then truly premium primary mirrors would move to the price range where they belong, which is in the neighborhood of more exotic systems. The prices industrial shops charge for a mirror in our category is not even close to what we get. We know, because two of our mirrors were used as benchmarks for an industrial shop to get into amateur astronomy. The prices were so high even at volume, that it causes the entire telescope system to be

very difficult to market. We spend more time on a mirror that many would imagine.

I've said this before, but I know personally of more than one shop that will spend about a day figuring one larger mirror, when we will spend three to four days in actual man-hours. However the prices we charge are only a small percentage more than most shops. Amateur astronomy is still waking up to what a premium Newtonian really is. There is less education per capita than one might think. So, what I encourage you to do is see for yourself. You will find many opinions out there, including some of the highest reputation when it comes to our product. But if you wish to learn about a newer mirror maker, your best bet is to get them side by side with a mirror of known reputation. CZ

Mirrors from Carl Zambuto are supposed to be the best (commercially) available. Is it perhaps that Zambuto shows the most consistency in his quality? Is it perhaps that he's the best in figuring large thin mirrors? And what about Swayze and Pegasus? And what about the (large) mirrors from Steve Kennedy? I've heard people say they are at least as good, maybe even better than those made by Zambuto! Can anyone help me? Thanks, Richard

Post Script: Richard, perhaps you could do us the favor of passing along links or references to those you have heard that say "better than Zambuto". That sounds interesting to me. I would like to read their comment or hear from them. Being a professional optician we know some things about physics here, one of which is optics quality and how it relates to the law of diminishing returns. To date I have never read a legitimate observing report that said any mirror of same aperture and telescope design outperformed ours, other than something on the level of "My Oblate-Spheroid brand mirror rocks, dude, and it blows that Zambuto away!!!!!" I would challenge anyone who wishes to address the issue to make a responsible (as well as reasonably articulate) comparison side by side at least to the level of Mike Harvey's observing report here, which is when one describes specific details. I say this because we have yet to see anyone make a comparison between two Newtonians and say we were legitimately outperformed. We still wait for the day. CZ

Preston, Indeed it appears Mr. Kennedy has been doing this for some time (I didn't see a name attached to that facility, BTW). My point regarding reputation is, as far as I know he has not yet established a well-known working reputation in the industry of amateur astronomy. Nevertheless, it sounds like he has a very good background and we welcome him to the community. We wish him the very best of success. CZ

Good Afternoon Carl, The following site is Steve Kennedy's optics web page: www.kennedy-optics.com/ for 22-32" mirrors. I see no reference to any other makers, but it would appear that he has been doing this for a while from information given at the site. Best Regards, Preston

My Goodness Erwin, if more people thought like you this hobby would be a lot further along than it is today. Glad to see some of what I call good old' common sense. Some notes for you- you might talk to Rick Singmaster, as well as Pete Smitka at Mag 1 and

Tom Noe at Teleport, because they're the ones who sell the scopes and they know these people because they have dealt with them. Also I'll mention that Rick usually goes to the Rocky Mountain Star Stare every year, so talk to him and see who he knows out there in CO. "Ratboy" comes to mind, who posts observing reports to SAA on a regular basis. He's somewhere in the Rockies and owns two Z-mirrors that I know of, a 10" and an 18". On the subject of side-by-side comparisons- to whom it may concern Mr. Singmaster has an open invitation to any mirror or scope maker who wants to challenge him in a side-by-side contest. They can choose any 5 Starmaster/Zambuto from a major star party and Rick gets to choose 5 of the other represented brand. They all set up side-by-side and do a full-tilt performance test. Still looking' for any takers. None have risen to the challenge as yet. (And you can leave your spec sheets at home; they have no weight in a performance test) One more item, Erwin, please don't blow my cover on the marketing scheme. It takes a lot of persuasion to keep 590 people signed onto a group and making nice comments from time to time... CZ

As they say in Missouri, "show me". And the proof is in the pudding. And one picture is worth a thousand words or should that be spec-sheets. I am in the market for an 18" or 20" scope and am trying to make an educated purchase. My locale is in southern Colorado and I am looking for a Zambuto mirror owner who attends star parties in the Denver or Colorado Springs areas. I would like to perform a side-by-side comparison - the acid test. For all I know this mirror group could be just a clever new marketing scheme. Hey it worked for Howard Dean financially anyway for a short time. I have been partial to Galaxy only because they are within 100 miles of me in Buena Vista, CO and would be convenient for a return if there were a problem. I will expand my query to any Zambuto mirror owner in the entire state of Colorado. Cordially, Erwin Miller

Chipped Mirror from Shipping

Gary, Please contact Tom Noe at Teleport. There are several levels of solution to this, depending on how far you want to go with it, right up to replacing the mirror. I'm sure that Tom will be happy to work with both yourself and the seller to find the best solution, whatever you decide that may be, and I will work with Tom as necessary. In the worst case, the mirror can be replaced. There is a protocol for doing that by which the serial numbers of the mirror and scope can be preserved. You might want to take a digital image of the damage showing the full aperture of the mirror for perspective and send it to both of us. Also, send me the information on the serial number. Sorry for the disappointment, however rest assured it is fixable. Carl

Hi all: I hope someone can offer some comforting advice. I was recently thrilled to have been able to purchase a used 10" Teleport, in like- new condition. Unfortunately, the seller failed to lock down the mirror properly before shipping, and I was devastated to discover two significant chips lying in the bottom of the mirror box upon inspection. One is from the periphery of the mirror face, about 1/2" x 1/4" x 1/8" deep. The other is 1/2" x 1" x 1/8" deep, on the side. How significant is this type of damage? Can it be repaired? The seller suggested blacking out the affected part of the mirror (he also has offered to take the scope back, if I am unhappy with it). What effect would this damage have on the

resale value of the scope? Help, please! Gary

Will Scopes Beyond 14" Show More Detail on Planets?

Let me "embellish" just a little bit on a former posting. Geoff linked to one good answer to your question. If you visited that link, I'll describe just a bit more about the experience looking through the 22" scope. The owner had a Bino Vue on Saturn at about 425x. The three dimensional experience combined with that aperture, which produced incredible saturation with Saturn, was otherworldly. It was like being out in the space between here and Saturn, observing it from there, rather than here on Earth. It was so saturated in its color that all disbelief was suspended. It was more "real" than image-like. It felt like you could reach out and hold the planet in your hand. It seemed that real. I know no other way to describe it. The best planetary scope you can own for good seeing conditions is the largest aperture that is fully diffraction limited (by the standard we use, I would add). For the time being, in my rarely-to-be-humble opinion it would be a 24" Starmaster.

If you have more questions, you might ask Mike Harvey, or you could also go to the Starmaster forum and look up an older posting by Thomas Back where he describes his "electrifying" experience through his 20". CZ

It is argued that you don't need to go beyond 12-14" for planetary observing. Bigger scopes will not reveal more detail, the same details are just more easily perceived (another benefit would be that you can detect more color on planets with big scopes). Is this true, or will bigger scopes also revealing more detail, given the right conditions? Richard

Geoff, I think you "caught" me. The reason is because you guys spend your time under the stars observing and you see this every night you go out. Me on the other hand, I spend the majority of my time in a dark room looking at shadows on a piece of glass. My time at the eyepiece is quite limited these days, as I spend most of my leisure time elsewhere as a diversion from mirrors and telescopes. On the increasingly rare occasions I do get out and observe I'm usually amazed all over again at how incredible this stuff is. Go figure. CZ

Carl, I'm always amused at the difference between you looking through a Zambuto telescope and the rest of us. You always seem to be surprised and amazed by what you see. We, on the other hand, just take it for granted! -- Geoff Gaherty Toronto Centre RASC http://members.rogers.com/ggaherty/

Hello Markus, Very nice to hear from you, it has been awhile. Yes, we finally got the 24's under control and in the tolerance. They take a long time to figure so we don't do a lot of them, but we will likely do a few every year. Thanks for the Jupiter report :) CZ

Hi Carl, even here in Germany we see planets :-) and my 20" Starmaster with its CZ mirror worked pretty well 2 nights ago on Jupiter, seeing was such good, that moons of Jupiter have been balls (and for a 20" you need a dam good seeing and dam good optics

to see no dancing balls at Jupiter's moons). First I used a nice Questar 3.5", nice Jupiter with 2 bands and maybe a big red spot, than I went to my newest baby, a Ceravolor HD 145 MakNewt. This handled already powers up to 230 perfectly at Jupiter and not only a lot of details became visible, but the red spot started to show spurs of color. Than I went to my big baby, the 20" and oh no, it was colorful, my eyes glued at the red spot looking for the fine color nuances and the small turbulences in the spot. Usable max power was about 500 times (please note we are at 49° north latitude), that's the, limit where I saw a small breakdown in sharpness when I surpassed that power, but since Jupiter is a low contrast object, 500 power is already very high, if you still have a razor sharp ultra contrast image. Sometimes when CZ have a bit time to make me a 24", than I may upgrade to this size with a Starmaster DOB (who is simply the best in the world, at least for me) clear skies to USA from old Germany Markus Ludes

Richard, It appears Mike purposely (as well as tactfully) left out the specific name of another mirror maker. Starmaster has used a number of mirror makers through the years, depending on what was available. Different ones came on board at different times. Counting past as well as current I personally know of no less than seven different opticians who have mirrors in Starmaster telescopes. Rick has always sought to provide the best performance available at each representative period in time. It is no different now. As most folks know, Starmaster has moved to the point where they are now exclusive with our product up through 24" aperture. That last size is only very recent as far as exclusivity with our product goes, because we were ready to do that only a short time ago. There was a time when we only did 7" mirrors for Starmaster (it seems so long ago, now). I must add here that comparing Strehl ratios or specification sheets will tell you very close to nothing about what you see at the eyepiece. It is about the craftsmanship of the mirror maker, and quite frankly, nothing else. The added contrast that Mike is seeing is in very large part a result of polish quality and surface smoothness. The quality of the edge also plays a factor. None of those aspects show up on documentation in any meaningful way that is consistent in this industry. It is my belief that the value received for any given Starmaster at any point in history has been exceptional. That is how they established the reputation they have, and have become the company they are today.

Note that the telescope itself has evolved over the years, as well as the optical quality. At this point Starmasters cost more money than at any time in their history. There is a reason for that. One is, the telescope itself is the best instrument today that it has ever been, and the other is, they pay more for their mirrors from this vendor than anyone else to date. So I'm going to ask that we not do a spec sheet comparison, as it would in truth be meaningless, and would certainly do more harm than good. I'll also ask that we not name other mirror makers in combination with reports of lesser performance here in public. You're welcome to call Rick Singmaster himself, as he is the one who sold the telescopes. He will tell you how it is. You can ask him about his standards in field testing, you can ask him about optics availability over the years and what has changed. All Starmasters contain good mirrors. None have any gross defects and all perform well. At the same time, I believe Rick will tell you that Starmaster telescopes through 24" aperture presently provide the highest consistent contrast to date, and we aim to keep it that way.

Thanks for your query. CZ

Great report! But also a bit worrisome, how is it possible that there is so much difference between two equally sized (24") Starmaster telescopes? Are some Starmasters more equal than others? Are there "premium" Starmasters vs. "ordinary" ones? Perhaps you could give the specifications of both mirrors - mirror maker, thickness, Strehl ratio, etc. It would be interesting to compare them. Richard

I need to add one more thing that I overlooked. I said the following: "All Starmasters contain good mirrors. None have any gross defects and all perform well." Let me add this for some perspective: Because of stringent field testing as well as choosing the highest quality optics available at every point in time, Starmaster has consistently been recognized as the highest performing telescope in the large Dobsonian class. In other words, they have always been the greater performer. Any historian of amateur astronomy can document that well beyond reasonable argument. Long before I came on board Starmasters were showing planets at over 1,000 power, shocking the uninformed and uneducated at the major star parties where the seeing was good. The new understanding of large, fast mirrors being superb planetary performers, for example, was established well before I came on the scene. (I did have a predecessor, if you check your history.) So keep that in mind when you consider any differences between other optics and the contrast we provide. The other ones are not bad by any stretch. Quite the contrary, but we have simply added an edge, by making them a notch better. CZ

Daniel, if you correspond with Kennedy please do give him my regards. We look forward to your report on ***Cloudynights***. That's an impressive, and possibly unprecedented lineup for one report. Sounds like a very high caliber grouping, we feel honored to be counted among such company. I'll be particularly interested to know how the Beck system did. I understand that Ed is an "old timer" from a long ways back, with a lot of experience. Carl

Carl, I was with Kennedy at Pinos and he commented that the star test on one of your 20's was very impressive. Unfortunately, I cannot say the same about the rest of most other brands of optics at Pinos. They are too often a hit and miss and personally I'm tired of dealing with it. I'll keep the names to myself as a courtesy. We wish you the best. I will release the biggest planetary shoot-out ever for ***Cloudynights.com*** this summer. Here's my line-up for you guys: 12.5" Portaball F-5 Zambuto Optics - curved three-vane spider, 14.5" Starmaster F-4.3 Zambuto Optics - straight four-vane spider, 16" Lightspeed F-5.8 Wilkinson Optics - straight 3 vane spider. 24" F-4.6 Osypowsky truss Kennedy Optics 8" F-9 TEC apo 8" F-9 TMB apo 9" James G. Baker apo 10" F-16 Carl Zeiss apo 13" F-6 Newt. Kennedy Optics three vane curved spider 12.5" f-6 Newt. Beck Optics three vane curved spider Best, Daniel Mounsey

Daniel, I'm pleased to see that you're one of the folks who describe what you see in the eyepiece on objects in focus. The star test is valuable for the trained observer to evaluate an optic and such reports are probably necessary in a field test report. At the same time, in our opinion the actual in-focus object descriptions are the most valuable to the lay public, as such descriptions can be translated into actual experiences more people can

relate to. So I'm pleased to see your descriptions of how the objects look. I truly look forward to reading your report when it comes out. Carl

I have to admit though; I am really hooked on these big mirrors from Kennedy and Zambuto. I've never seen such consistency in my life and planets just scream at you. At Wilson where we do planets, we get an inversion layer over LA and laminar airflow from the west coast. The two combined are deadly with seeing and allow big optics a chance to really shine. Even when using a 12.5" Zambuto, equipped with IAD coatings, the texture of the B ring on Saturn just killed me. It literally took on a vinyl record appearance. In Kennedy's 24" we had Mars near opposition and just pounded that planet with a pair of Claves and a Bino. The view in both was nothing short of sensational. I think with Zambuto doing most of the mirrors 20" on down and Kennedy doing mirrors 20" on up, both of you combined are Nitro & Glycerin. Daniel Mounsey

Pegasus First Look

(Did I ever tell the story of when I looked through my first Pegasus mirror? -let me know and I'll recount if it hasn't been done) Please do share this with us!

Thanks, Darren. Back in the early 1990's I used a 10" F/4.8 that I had hand-figured. It's a short tube scope and I used it for sidewalk astronomy. I was used to always having the "best planetary images on the block", because as the amateur community could now deduce in hindsight, the planetary scopes were mostly the refractors, most of which never got larger than 6". So one can imagine in those days that a smooth, diffraction-limited 10" Newtonian would have very few equals, as commercial scopes would not compare. Only the rare mirror done by an advanced amateur would show the performance I was used to, which was the category I fell into, however I didn't consider myself "advanced" at that time. The old myth that has now been laid to rest was for the greater part a reality, regarding large aperture telescopes. If someone wanted large aperture that was good, they would figure it to F/7 or, in the case of Clyde Tombaugh, F/10. The big-gun Newts of those days were not considered planetary scopes, but rather affectionately called "light buckets". Few people if any expected large scopes to do well on a planet, including myself. I even wrote an optics article for a local club on that subject giving an example I'll relate.

In those days there were no Starmasters, the big premium scope was another popular brand, one that doesn't use "bendy-thin" mirrors (another subject, BTW). We had a club party on the top of Glacier Point at Yosemite one weekend, when the seeing became very, very still in the middle of the night. My scope was an 8" I had hand-made, a very early mirror for me, one of my first five pieces. On the hill also was a Cave 8" F/7 on equatorial mount, an orange C-14 that was supposed to be very good, and a big 20" premium commercial DOB (the other brand) with the upgraded mirror. At one point in the middle of the night I put in a Barlow on my 8" and saw a Saturn I had not seen before. I was almost at 50x per inch and saw radial lines across the rings. I called everyone over and we all looked, including the club president who was a veteran observer and astrophotographer, and we all agreed we were witnessing Saturn's spokes. I

hyperventilated. So then we thought, well, what about the C-14! We looked. No deal. No spokes. Couldn't resolve them. Then we went to the 20" DOB. Sorry, no good there either. It just did not show the detail the 8" mirror showed (I had collimated that scope myself earlier that evening, so we knew everything was right). The Cave mount was so shaky the owner didn't run it past about 100 power, so the 8" Cave attempt was futile as well. So that night five guys took turns sitting on the ground for 20 seconds each to watch Saturn drift through the field of an 8" Newtonian, which whipped the pants off the two larger scopes. Now, don't get me wrong. THAT'S THE WAY IT WAS in those days and nobody expected different. There is no blame here. The 8" scope was F/6, the Dob was F/5 and BIG.

Forget about it, it was not expected to show the planets like a refractor does. For those of you who are new to the hobby, that was accepted, almost as if it were the laws of physics (Look how far we've come). The first major commercial change, as I understand it came from someone who helped me quite a bit early in my career.

So back to the story, I had my 10" F/4.8 at the Pettinger-Guiley Observatory in Puyallup WA on a public night. As usual I was used to showing everyone the best planetary view around. Then I saw and heard about an 18" scope that was home-built. Well, I had a soft spot for home built scopes because every scope I owned to date I made myself. I always liked to shoot the breeze and trade ideas with scope makers. So during the course of the conversation out of courtesy (I didn't want to hurt any feelings) I asked for a look. Now understand I was certain that an 18" F/4.5 large aperture mirror was going to show a mediocre planet at best. They were looking at Saturn, same as myself. I went to the eyepiece and had the shock of my days.

The three moons that I had to look hard for in light polluted skies were just hanging there like Christmas lights staring back at me, and the planet was beautiful. There was no image degradation over the view in my 10" and the color was brilliant and beautiful. The planet showed detail I had never seen before visually, and so on, etc. Anyone who has observed Saturn through a good 18 knows what I'm talking about. It was awesome, and just plain shocked me. For the first time, the comparison view in my 10" was dim and uninspiring. My whole paradigm shifted in that moment. So I swallowed hard and asked kind of nonchalant, "Uh, so who made the mirror?" The reply was "Pegasus". Oh, I see. “So, uh, Pegasus-who?” Well you can bet your britches I made a mental note of THAT name. John went on to single-handedly as an optician (in my opinion) along with the help of Rick Singmaster lay the foundation that changed the paradigm of large, fast mirrors being superb planetary and high contrast instruments. My hat must come off to such a man and such a contribution. CZ

Fused Silica...

Bob, I think Mike Spooner covered the issue well. I'll add my thoughts. Keep in mind we don't work low-expansion glass in this shop. Here are the points I would make.
1. You have already discovered the pricing issue. I have always considered a rule of thumb to be that quartz for example is about 10x the price of Pyrex.

2. We already know that we can put a figure on Pyrex that has real Strehl ratios in the high 90's.
3. Low expansion substrates generally will have higher density, meaning they will be greater heat sinks. That means longer equilibration time. In my thinking, quartz for example is good for secondaries, but not an expedient choice for primaries, for the above considerations. I think of low expansion glass as primarily for shop tooling. That is, I would want to use it for reference pieces, such as flats and reference spheres. The reason is, from my understanding you can indeed get a smoother figure on the small scale, avoiding some of the low-level discrepancies that Pyrex will produce due to minor inhomogeneity and flexure due to temperature during figuring. You might take another look at the image "***phaseshift10***" in the bench images folder with this in mind. The Pyrex created a narrow higher-order slope error on two edges, as shown in red on that image. This would probably have been eliminated using a low expansion substrate.

Now mind you, ***phaseshift10*** has an RMS of 1/45, which is a Strehl ratio of .98, which leads me to my last point I'll make, using an example. The actual mirror, Phaseshift10 was set up side by side with its Zerodur counterpart at a dark sky star party in the south. Another exact same model scope housed a mirror with a Zerodur substrate having a .99+ Strehl ratio as measured by the same phase-shifting interferometer that Phaseshift10 was measured with. So you get the picture here: Two telescopes set up side by side. One has a Pyrex mirror with a .98 Strehl ratio. One has a Zerodur mirror at .99+ Strehl ratio.

The result at the eyepiece, The Pyrex mirror came to equilibration about 30 minutes earlier than the Zerodur mirror, and so, during that timeframe outperformed it. After that, they were seen as equal. No difference was detected. Keep in mind we're talking about mirrors that are about 1" thick, and there was that much difference in equilibration time. The problem with higher-mass substrates is their equilibration issues. For example we observed a 25" other-brand large DOB with a 2" thick Zerodur mirror a few years ago. The reports we have are that the image "boiled" all night long. It never seemed to come to equilibration. That scope was sold and now the owner has a 24" Starmaster with a 1.75" thick Pyrex primary by ZOC. Some folks get hung up on this idea that the low expansion substrate will not show a figure change and so is desirable. I say that the issue is the heat coming off the mirror. That is what damages the image more than any figure change. You see, you're not going to get the performance the substrate can offer until the mirror is within "x" degrees of ambient, that being, equilibrated.

That is because the heat coming off the mirror, and the boundary layer, interferes with the image. But common sense will also tell you that at that time, the figure (of Pyrex) will also be equilibrated, no? So it all comes together at the same time. So which is better? What you want is to get to equilibration as fast as possible, for both issues. And that is of course the very reason we use thinner substrates in many cases where applicable.

And a sub-point: Even though the figure does change more with the Pyrex during cool-down, the veteran star tester can make a reasonable determination as to what amount of spherical aberration is involved with the Pyrex. We're of the opinion that it isn't enough to cause any degree of image degradation that is worthwhile anyway. Understand that

while the mirror is cooling and the heat is rolling off, it is *still* a smooth mirror in its overall figure, it will just be slightly overcorrected. It would have to deviate more than 1/4 wavefront to even begin to be an issue, and during that time the boundary layer is causing more of a problem anyway.

So bottom line, we vote for equilibration as soon as possible. Substrate figure-change as far as it applies in reality, is essentially a non-issue as far as we're concerned. You can probably get a slightly better figure in the low expansion substrate generally, but I believe it will be lost in the added equilibration time, for starters. And furthermore, the reality is, once you get past about .95 or .96 Strehl ratio and have a smooth surface and good edge, there is not going to be any noticeable difference at any reasonable magnification. Those are our thoughts on low expansion substrate. Now, if anyone has a nice quartz *flat* they would like to get rid of... CZ

Bob Mazzullo wrote: Now granted, these prices are extravagant (to say the least), but cost aside, does fused silica have some sort of real practical advantage over Pyrex? Or, as stated before, is this more a misconception, especially for the ATMer, than anything else? Additionally, since Carl can coax a fabulous figure out of his Pyrex blanks, does careful polishing and attention to detail obviate the need to use fused silica at all, based on the information copied above, sent along with the quote? Any thoughts, details, etc., regarding final polishing and figuring fused silica would be greatly appreciated. I read through some of the ATM archives, and a fellow named Mike Spooner seems to have worked with materials like this. Mike, if you are still out there and subscribe to this list, can you comment? Thanks, Bob Mazzullo

Mauro, I always appreciate your postings, I think they are thoughtful as well as articulate. I also appreciate that you can translate theory into practice. As one can surmise by my postings we come much more from practice and empirical results than theory. What I gave were two observations concerning the behavior of zerodur (specifically) in the field. There are other observations, however I can't define them so readily, as they are general observations over time. There is not a large body of data on the field performance of low expansion glass that I'm aware of for this industry, that is, at the eyepiece. The amateur industry is just now coming to the point where the more experienced are beginning to understand what a well-made optic actually does. I mean even Terence Dickinson, as I understand it, promoted refractors more exclusively as premium planetary instruments until he bought his first Starmaster.

So the amateur industry is still in its infancy, and we're on the ground floor. 15 years ago we didn't know that a large Dob could be a planetary instrument. That being the case, we haven't gotten to low expansion substrates as an industry as yet. Perhaps that will be next. I appreciate that you supplied the specific information. I was going to make a point in reply but you already did that below, that being, although we do know what the internal thermal conductivity of a material is, we don't necessarily know at what rate it can expel heat to the surrounding air. What Rick and myself have in common is this: we draw our conclusions based on what we see in the field at the eyepiece, very much as you do. We look at the theory, but we always weigh it against the evidence. Sometimes the evidence

seems to defy conventional wisdom. Anyway, it appears you're on board on this subject, and so can be at hand as it develops over the years. I think what would need to be done is optics of same thickness and Strehl ratio must be fabricated, and then tested in the field side by side.

I think you make a good point regarding the thickness and strength of the glasses. I had thought the same things. If I were going to go for a cost-no-object mirror I might consider quartz at a significantly thinner aspect ratio. It would not have the same behavioral problems that thin Pyrex has, and so a very nice figure of revolution could be obtained with little deviations locally. You also make a good point about the material behaving different during figuring. What happens is primary ripple is a large cause of contrast loss. Primary ripple is a result of the facets of the lap removing glass, causing a particular surface roughness as a result. The faster the glass is removed, the coarser the surface must necessarily be. ***We remove glass relatively slowly, that is, less in one stroke, and so keep our surfaces smoother.*** The low expansion substrates that are harder by nature will give up their glass slower, producing a smoother surface. But if you think about it, in the end it may trade off evenly. The labor will probably be the same. For an exercise, you might get a bid from an industrial shop (not one who competes in the amateur market) to make a Zerodur mirror. You will be shocked at what it costs. The problem we face now with going further with all of this is the market on the whole is unwilling to pay the price for the very best mirrors in any real quantity. There are folks who are willing to pay $1,000 US per inch of aperture for a refractor, but not for a reflector. Paul Leuba makes a VERY appropriate point concerning the value in a premium reflector. In any case, until the market is willing to pay the money, you will not see opticians rise up and fabricate such optics for commercial use, such as Quartz mirrors with rouge finishes interferometrically tested in a vertical setup. Thanks again for the specific numbers on the properties of the glass. We will look at that as we consider the potential value of each one over time. I haven't seen any argument yet on my stated performance aspect of Pyrex, and whether it could be improved upon given the factors I mentioned. That is certainly open for discussion. If it can be empirically determined somehow that there would be a real gain somewhere, perhaps we could find an excuse to make a 12.5" quartz mirror for $5,000.00 :)

BTW I'll mention that there is a possibility by an unusual course of events that we will be working some Zerodur in the future. I won't provide any details until it becomes a reality, but when it does and comes to the public awareness through the appropriate channels then we will talk about it more. Thanks Bob, for supplying the material quotes. CZ

Zerodur have 45% more heat conductivity, But if the convective cooling is not enhanced proportionately that is useless. To exploit Zerodur one have to change the design a little bit: make blanks 12% thinner (which is keep the same bending stiffness) and enhance the air cooling (bigger fans) so that the extra heat flow that zerodur is able to carry (faster) on its surface is really taken away. It is reasonable: a 0.99 and 0.95 strehl mirrors should be not distinguishable (also because the special care in figuring Pyrex by Carl ensures smooth microfinish, but if another maker don't have the same care, Zerodur will be smoother than Pyrex and the difference in contrast will be probably seen. I now have two

scopes at home: one is mine (a 16" handmade) the other is a 12" made by machines and is from a famous industry. Believe it or not the latter have rings that look more similar intra/extra focus BUT deliver less colors and contrast. It has some diffused light between the rings (less contrast) that I think is due to the machines working faster and/or less gently and ultimately producing a rougher surface (I suppose). In this case, I suppose, zerodur would probably make the same microfinish (that is somebody could prefer to use a more costly material and a simpler process).

Mauro, I like your points and essentially agree with all of them, from the substrate theory to the shop testing, to the need for empirical evidence in the end. It appears you have thought this through quite carefully. Thanks for all of this, its good stuff. Carl PS it appears from your text layout that you use a Macintosh. Am I guessing correctly?

"mauro_dalio" wrote: The use of a different material calls for a different design. The first obvious point <snip But the final product is not going to be better, only "better known" (which is a need for a costly aerospace program, not for an amateur).
Re: further question regarding fused silica...

Hi, can either/both of you address the differences between quartz as a mirror blank material and zerodur and Pyrex? Thanks ... Clear Skies, Chuck, I was under the impression that was what we were doing in general. It would help if you could be more specific. A complete answer to your question could be a long treatise bordering on a short book as there are many aspects related to it. And keep in mind I don't work with quartz or Zerodur and Mauro is not an optician, if I understand correctly. If you pose a specific question, I'm sure somebody could offer something. Carl

Chuck, It’s not a dumb question. I just can't answer because it’s not specific enough for me (personally). A mirror blank has many ramifications to the mirror maker. Mauro answered the aspect of chemical composition. That's one part, and maybe answers your question. But I think like a fabricator. For the mirror maker that has to be translated into how it affects them. There will be differing behavior during fabrication of various considerations. There is surface response to polish regarding speed, and angstrom surface roughness. There may be a change in grind approach. There may be a change in polishing agent. Then there is behavior when in use. All those things come into consideration when considering a mirror blank, and each aspect mentioned is typically multi-faceted. I'll tell you a cute story with apologies to a very talented apprentice. During training we had gone through grinding and polish, for the most part. When he felt he was ready to go on he wrote and said, "Please send instructions for figuring". You can't imagine how we smiled when we read that. We're still working on figuring instructions. Its been a long time, and is proving that it will still be quite a while, which is normal and natural, BTW. (It seems to me that to turn out a good mirror maker should take about 5 years at a minimum.) I think you get what I mean. Carl Sorry Carl, I thought quartz was different from Zerodur or Astro Sital. I am most definitely a "newbie" just getting into mirror making with my 11 year old son, so I apologize for any dumb questions in advance ... Clear Skies, Chuck Hi, can either/both of you address the differences between quartz as a mirror blank material and zerodur and Pyrex? Thanks ... Clear Skies, Chuck

I like that you're starting with the 6" F/8 and working up through the sizes. That's the way to do it IF you wish to keep things under control and maintain some quality. I see so many who get aperture fever and do sizes that are far over their head, then either failing to finish the project or wind up fabricating a mess. I'm not opposed to folks taking on challenges, but at the same time you might imagine that we've always had a penchant for quality. It is much better to have a very smooth, reasonably accurate smaller mirror than a large piece of junk. And I should say, ANY size mirror is always an appropriate challenge even for the veteran, because there are so many variables that in the vast majority of cases there will be room to make it better. (Invariably the inexperienced ATM will not know where they truly are in the scheme of things, and have no idea how much better the mirror could really be). And once you fabricate a truly superb optic, it becomes a rare and valuable gem.

A specific example, Let's take a relatively newbie ATM who decides they need a good challenge and buys a 16" porthole at 1" thick with a dream to make a superb lightweight telescope. God bless them, because nobody else is going to smile upon such a project in the majority of cases, especially if they have not proven themselves with a same size substrate of standard thickness. What I would suggest instead is to spend a few bucks and buy a standard thickness 12.5" at F/6 for example, and turn the challenge into making that piece a mirror that cannot be outperformed. In the end what is more satisfying and more valuable- an astigmatic 16" with irregular non-symmetric zones, or a perfectly figured, smooth 12.5? I digress into a rant. I see so much wasted energy and so few truly incredible mirrors. To me, "exotic" equates superb, the kind that cannot be outperformed. Good luck with your continued mirror making endeavors. It appears your plan is sound. Carl Thanks Carl, I've started looking for a nice large quartz or Zerodur blank for a few years down the road after my son and I have successfully attended several mirror making classes and successfully worked our way up from 6" f8 to 16" f5 before we take on a large mirror. Thanks again, and thank you also Mauro

Quartz secondary

"The group" hasn't replied yet, and I'm waiting for them, too. Until they do, David, I'll say a couple words. I doubt you're going to see a difference. Chances are the secondary came from Protostar anyway. Keep in mind the scope was tested as a complete system before it was shipped. Keep in mind also the performance guarantee. (Are you outperforming the seeing conditions, yet?) We have yet to read a report where a 20" broke down because the seeing was good enough to go toward 100x per inch. If you want to spend the money for a "known" quantity and its not a big deal to you, there's nothing wrong with that. It helps our economy and the amateur astronomy industry specifically. But in all seriousness, I doubt you're going to see any difference. Something to keep in mind, although there may be some that disagree with me, the secondary figure (actual wavefront number) is not as critical as the primary. I won't go into the details, as it has probably been covered earlier. What is important is that the surface is SMOOTH (there's that word, again). Secondaries are done on planetary polishers, polished against flats. Generally the outcome is that they are indeed smooth, whatever the precise figure may

be. The figure has to be quite bad, or the secondary must have a bad turned edge for it to begin to affect performance. CZ

I seem to recall Thomas Back commenting that he changed out the secondary on his ZOC Starmaster 20 to a Protostar Quartz unit. Now Tom is an avid planetary observer and obviously has access to some pretty fine state of the art refractors for comparison. Along the same lines I thought about contacting Brian Greer and inquiring about the price and delivery time of a 3.5-inch quartz diagonal of known quality for my own ZOC SM 20. I know a high quality quartz diagonal of that size is not going to be inexpensive but I'm used to paying for quality. I just wonder if there is any noticeable performance gain to be had for critical high power viewing over the diagonal that came with the telescope. In other words is that equally important second component of the optical system up to the standards of the ZOC primary? Comments from the group please. Thanks David

ZOC 12.5" F/5.75 Sale Pending

A still rare but not unheard-of event: We have one (ea.) 12.5" F/5.75 finished and coated mirror ready for immediate shipment. During my sabbatical I got an itch to do a long focus project. We enjoy such work because we can use larger laps and can get the mirrors a little smoother overall in the large scale, as well as unusually accurate. Such is the case with this one. Specifications are as follows: Precision annealed Pyrex blank 1.6" edge thickness 12.5" diameter FL = 72.1 inches 90% AL coating with ion-assist quartz overcoat Weight=15.1 lbs. For comparison, the price is commensurate with the Hardin Astrola line of mirrors for same size. If you wish to buy this mirror please contact me directly at Stedystate@

Note: although our measurements will come with the mirror, we will not be quoting "numbers" in order to sell it, *so don't ask*. The figure on this one is very close to as accurate as we are able to fabricate and measure. CZ

I wish to thank every one of you who replied to the mirror offering. A sale is pending, and there are several interested parties in the event the sale doesn't go through. Looks like the mirror is going to Europe. For those of you who got your hopes up and are disappointed, you have my sincere sympathies. What I would probably do if I had my heart set on a 12.5" mirror and cost was an issue is look for a used older model 12.5" EL Starmaster, as one could probably be bought for about $1K more than the cost of the mirror that just sold, when one comes available. (And I put my money where my mouth is, because it is the original model 12.5" EL Starmaster that I own and use myself.) Thanks again, Carl

Mac formatting/Yahoo compatibility (OFF topic)

It's the web browser, Safari. It's very young in its evolvement. Although it is extremely fast and great for browsing, it has some rough edges, one of which is layout of text lines. They don't sync well with Yahoo. One of us needs to write to Apple and tell them to get that addressed. Mine does the same thing, as you can see :) Carl PS it appears from your

text layout that you use a Macintosh. Am I guessing correctly? Yes I am using Macs. But also I often type much too fast and do not re read (sorry, it is a deformation due to the too many things I usually need to complete when I am at work).

Using a Paracorr with an 11" f/5.4 ZOC Mirror

Hi, Bob, I understand everything you're saying and agree with it, except for the question you pose. ("I'm wondering if the image improvement is worth hassling."). I'm not sure what you're looking for, precisely. From the posts that follow as well as the history of Paracorr use it boils down to individual preference. It appears there is no "gospel" that is going to stick in every case. In the matter of manufacturers making a decision on balance, they have to draw the line somewhere, making the decision at what F/ratio they equip and not. There will be argument on both sides of that line, those who use a Paracorr on longer than the chosen point and those who don't use it on the scopes, which are faster and were balanced for it.

It is possible to rebalance your EL. One-way is to add weight at the back end. Another way is to adjust your side bearings, but you might want to check with the manufacturer before you do that. I moved the side bearings on my EL about 1/4". It was the prototype for the original line of EL's, and there was evidence it had been done before, but only visible when the bearings were taken off. So my only answer at this point is personal preference, if you need more than that try to give me a more specific question. CZ

I just received a tunable top Paracorr (latest model with compression fittings) to improve the image quality (coma) of my 14.5" f/4.3 ZOC mirrored scope (Starmaster Hybrid). Then I got to thinking about what it might do for my 11" f/5.4 ZOC mirrored scope (Starmaster ELT). I had wondered if the anecdotal tales of anything over f/5 not needing coma correction was correct. Well, the data coming from two of us looking at M35 tonight with and without a Paracorr and 20mm and 30mm Pentax XW ep's convinced us that the Paracorr improved the image in the outer third of the visual field. We could not quantify by how much and both agreed that one does not usually look at the outer edges of the FOV. However, it seemed to make a positive difference and I am wondering (Carl) if the image improvement is worth hassling with on a scope that was not designed to accommodate the extra weight of the Paracorr? I will be posting this on the Starmaster site to elicit some experienced comments as well. Thanks, Bob Schilling

Saturn Image Wes Higgins

Richard, I decided to bring some text back up as its good stuff. I'm going to highlight a recent posting of Mike Harvey's about observing with his 24", message #2128: "From the NEB to the pole, Jupiter shows a myriad of latitudinal tonal gradations in the 24". They're like very subtle belts and I can't count them all. In the 14.5", however, while you see a gradual color change towards the pole, you don't see the individual striations that actually comprise this tonal shift. Between belts, the 24" shows numerous 'blushes' and tonal shadings that are not detected in the 14.5". And, while detail in the GRS and GRSH is

visible in both scopes, it is 'easy' even to an untrained eye in the larger scope and 'harder' in the smaller." They key in his description is where he says there are a myriad of subtle belts that he can't count. And that's on Jupiter; mind you, the "low-contrast" object. The Thomas Back posting that has been referred to I didn't find the link here for yet, so I'm going to just bring some text over from Starmaster. This is a part of message #5986 at the Starmaster user's group: "I placed an order with Rick for a 20" Starmaster Go-To with Zambuto optics, and never have I been so impressed with a large aperture telescope before. I don't have to tell people on this Group what I mean, but to give one example, under near perfect seeing, with the 20" at 727x on Saturn, seeing the true Encke division (not just the Encke Minima), the inner portion of the A-ring's greater brightness, plus superb globe detail was electrifying. The Equatorial Band (EB) was positively easy. The South Equatorial Belt was split and very colorful -- browns/yellows/orange. The STB and SSTB were visible and that general area was orange/yellow/white. The South Polar Region was very pronounced and had a slight shade of green. That's what it is all about, seeing hyperfine detail. While I may only get 3 to 6 nights a year where I can see this kind of detail with Rick's 20" Starmaster on the planets, and while in less than good seeing (which is most nights where I live), my large refractors will show more stable and detailed images of the planets, it is for these super nights that I live for. For deep sky work, I find the SM 20" beyond my expectations. IMHO, the best large aperture Dobsonian is a Starmaster. Thanks to Rick, Carol, Carl and the guys at Starmaster for satisfying my 25-year quest for a superb large aperture instrument. Thomas Back TMB Optical TMB 100mm f/8 Super ED APO (Strehl .997) Astro-Physics 130mm f/8.35 EDF (Strehl .996) TMB 152mm f/7.9 Super ED APO Astro-Physics 180mm f/9 EDT (Strehl .9975) Starmaster 20" Go-To Zambuto The entire posting is actually much longer, if you wish to read it: http://groups.yahoo.com/group/starmaster_scopes/message/5986 CZ
I wonder how this beautifully detailed image compares to what you can see visually with a (large) telescope. Richard

Richard, You've asked a variant of this question before, although not specifically related to this photograph. Now that you have observed the photo, you might revisit Mike Harvey's observing reports as well as the link to Thomas Back's report of Saturn through his 20” that was referred to again recently, I believe in answer to your previous question. It’s all there, all of it. Carl I wonder how this beautifully detailed image compares to what you can see visually with a (large) telescope. Richard

10" f/6 CZ Mirror

The Zambuto mirror will likely be 1.6" thick at the edge. I don't know the Nova mirror thickness; you'll have to measure that. And I don’t' know the cell design, its an older telescope. It is not usually difficult to modify mirror cell posts, Call Rick if you need to, when he gets back from his road trip. He's delivering two 24's on the East coast. And don't wait to buy the mirror until all the details are worked out (I doubt it will last longer than a few hours). Carl I've got a chance at buying a 10" f/6 Zambuto mirror, made in 1998. I would use this as a replacement for the 10" f/6 Nova primary in my pre-EL Starmaster. Does anyone know how the thickness of these mirrors would compare -

actually what I'm asking is, would I need to replace the mirror cell, or could I plan on using the same cell? Thanks, Harry Boswell

Folks, In the few days I've made several replies to questions, which replies have not gotten through. I spent a good deal of time on them, which has apparently been a waste. I don't have time to redo them right now. From now on I'll have to save my text until I see that it gets through. (Now I have to see if this can get through.) My apologies to those whose questions have not been answered, when I'm able I'll start over again. CZ

Magnification Breakdown Theory

Hey guys, I have earlier postings to attend to, but I just read this from Nils and Mauro and I have to step in here: I have no idea what you're talking about! If all the information is already there then we can observe an image at low power and be happy. The reason we use magnification is to see detail. We have to increase the size, or scale of the image to see more information. How in the world can you say it is the same image at any magnification and so the imperfection must be in the eye? Yes, it is the same image, but you can't see the imperfection at lower power because of the smaller SCALE. Mirrors break down at a particular magnification because the defects in the wavefront created by the optic begin to show up when the scale is increased to a certain point. The angular resolution with respect to our eye increases. It effectively brings you closer to the object, which is why you can see more detail. That is why we use magnification in the first place, to see detail. Yes, there are considerations of exit pupil, eye aberration, and so on that make a contribution to the final image at different magnifications. Those factors are included in the stack of filters that are the optical train, and are added to all the other errors by all the factors that combine to form the final image. But to say that the eye defects are a greater factor in image breakdown at a higher magnification as opposed to the mirror is flat out wrong.

All you have to do is put two mirrors of same aperture and different optical quality side by side to see how that works. Furthermore, the notion that the eye is a major factor in image degradation at higher magnification is backward. Defects in the optical quality of the eye have LESS effect at higher magnification, (I exclude floaters) as the light cone is intercepting a smaller portion of the lens that is the eye. An example, people with astigmatism in their eyes can take off their glasses at highest powers and see less effect or none at all. Also note there will be less difference between the focus positions needed for different people at higher magnifications. You can use less expensive lens designs at higher powers, also for the same reason. Such a concept is why people use aperture masks on inferior quality optics. ***So overall, there is less difference between what people will see at higher magnifications because of the differences of their eyes, and more difference because of the quality of their optics.*** Then at lower magnification, the mirror becomes less of an issue and the eye becomes more of an issue. What I was reading in your postings guys was the opposite in both cases. I can't let that sit as that is a major issue, and is in fact absolutely bearing on what we do here at ZOC and why we do it. The idea of there being a threshold due to lower intensity at higher magnification is another issue, and was stated correctly. Carl

One thing is that small-scale irregularities on your cornea or elsewhere within your eye are no longer averaged out. It is often used as a quality criterion of the optics (mirror usually) how small exit pupil you can use (or high magnification) before the image "breaks down". It is of course the same image, with some degree of imperfection, at any magnification, so the "breakdown" must be a phenomenon of the eye (or perception in general), not of the optics, even if a sharper image will of course look sharper, at any high magnification. Thus we should conclude that the "break down" of the image indeed is more due to
1 inability of eye to maintain resolving power at low light levels
2 too small eye pupil that enhances defects in cornea and eye
3 some other physiological effect If so the "break down" threshold (i.e. the max magnification that can be used before loss of details should be regarded more as a test for our eye/brain system than for the optics. Conversely the roll-off magnification (i.e. the minimum magnification which shows all details, further magnification resulting only in a larger image but with no additional detail) should indeed be the REAL test for optic? (Unfortunately it is no easier to decide weather NO additional details are appearing at all).

Friendships over time in astronomy

Mike, Thank you for posting your letter. I've made many references to Bob Goff on this forum over time, but never in such a manner. What you've done is articulate a concept about how he affected people and what he accomplished in a way that I've not been able to do. You have expressed my sentiments as well, and done it artfully. Thank you for that. As I wrote to you personally, as time goes along somehow I gain more and more appreciation for who and what Robert Goff was. Somehow he has more effect on me today than he did when he was alive here with us. I do miss him.

Carl Below is something I've been meaning to write for some time - it's an attempt to express my regard for a friendship I valued. Through amateur astronomy I've found many rewards beyond a mutual love for the heavens. I make no claims other than this is the memory I prefer to keep. --Mike

Quartz Secondary

Adam, I'm finally getting to your question, Hello Carl/all I am going to de-lurk to pick up on the subject of secondary quality and how it affects overall system performance. There seem to be 2 schools of thought. The first says that the figure of the secondary is a vitally important link in the optical train. The second (I think Carl belongs to this group) maintains that "The figure has to be quite bad, or the secondary must have a bad turned edge for it to begin to affect performance" and "What is important is that the surface is SMOOTH" I belong to both schools. The figure IS a vitally important link, but at the same time its criteria is different than for a primary mirror. Can you help me with my understanding of this?

This is a VERY complicated issue. I think we should go one step at a time. I'll answer a little bit and if you want to go further we'll go deeper into it, and if you want to go further still I'll have to get out some books. Is it possible to do so, and if so how do you add up the average figures of a primary and secondary?

I would forget about that one. You're going to have to decide what common denominator you want to use and that's going to be tough. ***For example you can't add PV spherical aberration as defined by a knifedge test on a primary to PV waves as determined by interferometry, which is required to test the secondary mirror***. Although people on other forums still ignorantly compare numbers from both tests as the same thing, they are different animals. There was a strong argument that the distance of the secondary from the primary meant that it did not need to be of absolutely top quality. Does this make sense? Why?

A thought experiment is to stand one foot from a bathroom mirror with a laser pointer, pointing directly back at itself. The beam returns to its source. Now tilt it 1° off and see where it lands on the target. Now keep the tilt at 1° off and move back five feet. Notice the beam is now further off target. The slope error in a flat mirror will have greater effect at a further distance, and less effect closer up. How does one theoretically form a minimum specification of a secondary mirror for use with a high quality primary? I don't have a formula in my back pocket. One could work through it I suppose, but it won't be easy. Keep in mind also the tilt of the secondary adds a factor of .707 to the equation. My suggestion is to forget about the primary, and decide what kind of secondary mirror is good enough to not noticeably affect performance. Because of its proximity to the focuser, a 1/4 wave PV as tested by interference fringes is likely good enough, and I have good reason for saying that, but is the subject of more discussion.

1/8 Wave Secondary is Good Enough

Today's standards are such that you can get a tested 1/8 wave secondary, such as from Protostar. I would say that 1/8 wave is certainly good enough, and the results prove it so. Most of our product is coupled with minimum 1/8-wave secondaries. So unless you're dead-set on theorizing about numbers (tell me it isn't so) save yourself a lot of effort and take it from results. Buy a 1/8-wave secondary that has been reliably tested. If you need to explore the subject in more detail, we can do that as well. Carl

Prisms

John, I don't know the reason they recommended one *in place of* the flat, but I do know they were used in days gone by. Perhaps prisms were more readily available, maybe scopes were much more rare and flats were not on every astronomy supplier's shelf. Heck, there probably weren't any suppliers in those days. I do know there was a time where if you wanted a telescope you essentially had to build it yourself. The issue with prisms is you have more surfaces to deal with, and then the optical quality of the glass on top of that. They are no longer used today from what I understand. The flat has one

surface, and the light doesn't have to pass through it. Carl

Carl: Just curious, but I made my mirrors from the old Scientific American books. They were the only things available when I made my first 6-inch f/8 back in the 40's. So did the same when I did my 8-inch f/6 more recently. But, I noticed in the old books they recommended a prism for a diagonal in place of a flat. Is there a reason for that? I did use a flat in both my scopes as that is what I had available, but would a prism introduce more errors or problems for a homebuilder? John Meacham High desert of California (where the seeing is great if that dam wind ever dies down.)

Secondary Testing

Thanks for the reply Carl. I have no wish to delve too deeply into textbooks, and indeed I would wish to match a known good secondary with a premium primary. Empiricism is usually fine by me; however, a little understanding helps. I still do not understand the previous quote you made ("The figure has to be quite bad, or the secondary must have a bad turned edge for it to begin to affect performance") and how it jibes with your view that 1/4 wave is probably good enough and 1/8th wave certainly is. By a "bad" figure I would mean either "rough", or worse than 1/4 wave surface. Although usable, I think that worse than 1/4 wave could border on causing problems when it comes to premium performance. Unless the answer lies in the wave front numerical difference between interference tests and other tests of the same mirror. With a parabolic mirror I remember that your view is that interferometer gives approx. a 2.5 factor worse number for wave front compared to a knife-edge test. Does the same sort of thing apply to flats; interferometer vs. fringe? If so a 1/4 wave flat measured by an interferometer would be (say) 1/1.6 wave by more usual test methods this to me would qualify as "quite bad". Fringe analysis on flats *is* interferometry. That is how they are tested, against a reference flat.

I went through the flat testing process at Bob Goff's shop; he was a flat specialist among other things. He had a nicely constructed booth all lined in black velvet with his overhead monochromatic light source and his test flats. He had a jig for suspending the test flat over the piece under test, lowering it until the fringes appeared (those are interference fringes.) Then he had a camera across the room (the distance was to keep field curvature out of the equation) that shot an image, which was reflected horizontally off the one-way mirror that delivered the light source from overhead (the mirror was tilted at 45°). The image was then analyzed by software.

I've got photos of the setup with flats under test somewhere, I'll see if I can dig them up sometime soon. Understand that a wave rating on a flat, as well as with 36 Zernikes via interferometry on a primary mirror is a two dimensional measurement of the entire surface. It only takes a one mm square peak to create a peak in the result, as well as a same size hole anywhere on the surface, to provide the PV rating. I hope it is understood out there that the PV number in such a case is generally a poor indicator of the overall performance of the piece (well, I can hope, anyway). An accurate Strehl ratio is much more indicative. This would apply to flats as well, which is why adding PV ratings of

mirrors and flats doesn't really tell you so much as to what is going on.

BTW Bob Goff's standard for flats was 1/10 wave surface. I have one of them in my scope, and I'm not going to let it out of my hands. Ever. I am looking forward to part 3 of "all methods of test should agree"! 8-) I've been procrastinating. There are a lot of irons in the fire right now. I'll be making an announcement soon regarding our certification, and the test method stuff does have a lot to do with it. I'll consider getting back on the subject soon. CZ

Flat Tester photos are on line.

I've organized eight photographs of the testing booth, layout, and actual test of flats as photographed in Robert Goff's optical shop in November of 2001, a month before he passed away. I wish to mention it was a rare privilege to be in the company and tutelage of Mr. Goff. The photos are in the photos section in a folder titled "***flat testing***". CZ I've got photos of the setup with flats under test somewhere, I'll see if I can dig them up sometime soon. Carl, I hope you can dig up the photos of the tester. I am going to try to build one. Robert

Confessions of a ... (closet refractorphile)

Jack Semura wrote: ... closet refractorphile. <Snip It's striking how in this high tech field where we argue about error measured in tens of nanometers, it is still the mirror maker's tradition of old style craftsmanship and an uncompromising covenant of trust that play such an important role. As I've mentioned before, I often stop to just admire the beauty of a mirror. When I look at stars, I'm always aware that I'm looking through the window of the mirror. Forgive me Carl, but I have this fanciful mental picture of Carl sort of inside a renaissance painting studying one of his mirror's with critical admiration, satisfied but still always trying to push the envelope to do a little better. The mirror is the soul of the telescope, and it is personal trust and this covenant of quality that to me makes its surface even more beautiful.

Dearest Jack, I want to personally thank you for your comments. I've not heard such a phrase used before, but I think you describe it well by the concept of "an uncompromising covenant of trust". Indeed it is, and it is heart-warming (to use an over-used phrase) to read that. It has not always been easy, and I obviously appreciate when it is recognized. We don't have a Renaissance painting but we do have original oil by the astronomy artist Hulan Fleming, wherein I'm doing precisely as you have described, studying a mirror with critical admiration. And interestingly enough your timing is impeccable. Hulan is offering the painting for sale, and I'm going to help him out with it in my next posting. Carl

West Coast Astronomy Artist

I hope the moderators don't kick me off the site for advertising wares but I'm going to

help out a friend. My long-time friend Hulan Fleming, the west coast astronomy artist, did two paintings of yours truly in recent years. One of them is up in our shop here; I'll share an image of it with the group in the near future. The other one is owned by Hulan, he takes it with him to star parties when he is selling paintings and puts it on display to help sell prints of the same. For those of you who don't know Hulan, he has been painting astronomy themes for many years. His images are often used for Table Mountain Star Party t-shirts. In the past he has done a family portrait for the Naglers, and has had one of his open-sky star party images in Sky and Telescope. He does a lot of paintings of groups at star parties either looking through scopes, or looking at the sky. He has one particularly beautiful painting of the magnificent aurora that took place at Table Mountain a few years ago, with many pointing up and looking at the sky, including John Dobson, in the foreground. The painting Hulan has for sale is a 24"x30" original oil (yes, it is large). It is a collage painting of yours-truly behind the knifedge, and at a grinding machine. He has me looking *real* serious behind the knifedge, which is accurate most of the time. I've posted a medium sized image of the painting in the files section ("Fleming original oil"). I also have a 550K copy here available on request if someone needs to see greater detail. Hulan is asking $4,500.00 for the painting, framed and the artist signs it, and I'm certain it could be arranged for myself to sign it as well, if a buyer should desire that. If you're interested in the painting, please contact Hulan at: hulanfleming@... His address is: 24030 Lake Cochran Rd. Monroe, WA 98272 ph.: 360-805-9716 CZ

Elliptical grinding and polishing strokes

Tom, I see by your question you recognize that if a straight path stroke is run for a period of time (during polish/figure) it will create a zone. That is indeed the case. An elliptical stroke would smooth that zone out a good deal, and changing the size of the ellipse may be able to do everything you need. I think Lightholder has such a setup. We're of the opinion that rather than building elliptical capability into the machine it is easier to do something else, unless you have a Zeiss-style machine that you're building already. As we see it, the answer lies in the ability to change the pin position. We refer to it in-house as forward offset. That is a change in position toward and away from the pivot point of the stroke arm. A Strasbaugh machine has this capability, with most of the offset adjustment being away from the pivot, toward the front of the machine. Our figuring machines also have such an adjustment, although we use the opposite direction, that is, toward the pivot. If you have the capability to change forward offset position, as well as stroke length and lap sizes, you should then have full capability to fully parabolize any optic, and do it smoothly. The rest lies in technique. -Lots and lots of technique. CZ

I did some searching in the archives and I've found no discussion of elliptical strokes. Is there an advantage, especially for final figuring, to using elliptical strokes? Is it then worth it to make a grinding/polishing machine that can execute elliptical strokes? Would that make it easier to 'dial in' a well figured mirror...or at least get you closer to final figure than typical (straight, or non-elliptical) machines? Thanks in advance. Tom Krajci Tashkent, Uzbekistan

Surface Roughness

Yes, I don't see why not. We've done a lot of analyzing of mirrors on the site, without mentioning names of any commercial entities. CZ A person has asked me to help evaluate there 16.5 inch F4.3 mirror. A commercial manufacturer made it. I'm trying to help but I have only look at 4 different mirrors with the Foucault tester. This one seems to have excessive surface roughness as well as other problems. But right now I'm interested in knowing if this one has too much roughness. I think it does. This is not my mirror mine is much smoother.

Carl would it be ok to upload a Foucault image of this mirror to the Files section for you or anyone to comment one? Dale Eason

Rough Surface Mirror

Dale Eason wrote: I have added folder rough surface to the files section. I would like to know what people think of this. Generally it doesn't look great. It was advertised as a high quality mirror. Just a note here- "high quality" as a descriptor by itself can be nebulous. It doesn't mean so much. Its like saying "research grade". It also Foucault tests at an RMS of 58nm, Strehl of .2xx Using Sixtests and my Foucault system. Seems like a bad mirror to me. Based on such results I wouldn't disagree. Owner is considering taking it back to the scope vender and wanted some documentation to support its rework. Do you think these pictures are enough? I could post an image of the Sixtest analysis but I thought these pictures might be enough.

Here's what I think, Dale. In order for this industry to function the criteria for return should be customer satisfaction, not necessarily documentation from another vendor or group to prove it as less than good. As backup corroboration I think what you have done is quite sufficient. But the bottom line is customer satisfaction. If the company advertised the product specifically to be able to do certain things, (that's what we call a _performance guarantee_ which I will be addressing in greater detail soon on another subject) and it doesn't live up to the advertisement, the company should make it right. Now they do have the right to service the product by taking the customer through a series of questions regarding how they use it and how it performs under those conditions. The reason for that is, not everyone is a veteran observer. I have had many occasions where folks said the product did not do this or that, and after some discussion we found the problem and eventually they experienced the capability of the mirror. So do expect to allow the vendor to do some questioning. But if you're trying to prove something by documentation (using numbers) you're going to get mired into quicksand very fast. There is no way to prove unequivocally to everyone's satisfaction that a mirror is such and such. There is too much variation between methods, techniques, calibration of equipment, levels of skill, difference of opinion, and etc., to prove documentation conclusively.

For example, there are many customers in this industry carrying around pieces of paper that mean absolutely nothing. One such case was described a few days ago in another posting. At the same time there are those who say such results are "real" because of the

machine that spit them out, and the measurements of a reputable craftsman are "dreamed-up" or, "subjective and meaningless" (go figure). And I've witnessed a professional vendor saying that, so there is no way to win when it comes to documentation, Dale.

Nevertheless, based on the photos I would agree the mirror has some problems. The work you did is good corroboration for your friend's observations. I would probably approach it like this, assuming some stated guarantee exists other than "at your own risk": "The scope is not performing up to my expectations based on my observations at the eyepiece and they are, "x, y and z". So for some corroboration I sent the mirror to a friend who looked at the surface on the bench and indeed it appears to have a rather rough surface. He measured it with a knifedge and the figure according to his measurements appears to be less than satisfactory, with a very low Strehl ratio."

After that it's up to the vendor to handle the situation, at which time the customer is going to rely on the integrity of the vendor and/or optician. And that brings the subject back to *reputation*, something I've been harping on for some time now, and will continue to do so until they bring out the hook and drag me off stage. Otherwise, I wouldn't make too big of a deal out of contacting the vendor and making a complaint unless the vendor refused to make it right, or copped a bad attitude, etc. I mean, you don't have to go marching in there flanked by the members of the Zambutomirrorgroup on each side :) ...at least I hope not. CZ

Dale wrote: The fit to a parabola surface error curve is swamped by other error to be able to see much of the surface ripple. Yes, apparently that error would be called spherical aberration. I think it does show up in the best conic fit and I have uploaded it to the Files/rough surface/surface_conic_fit_diam_b.jpg. It is a screen capture of sixtests surface analysis. I would want to add that what is just as or even more important here is that according to your measurement the mirror fails to approximate the parabola, which is a conic at -1. The graph shows large scale deviations, which are higher, order, as being higher than 3rd. But the 3rd order aberrations must not be forgotten in the scheme of things. Apparently from center to edge the mirror does not approximate the parabola. If my thinking is correct it appears from your choice of a conic at about .83 that the mirror is under corrected by some 17% overall. That should not be overlooked in an overall figure analysis. As you said Foucault testing does not see non-figures of revolution very well but I think you can see hints of the ripples. But these might be larger than the smallest ripples that we see. The bottom of the graph is in mm. However I can see it in the raw data that is not recorded but shows up as intensity variation and it is graphed live during the test run. But that really is just another presentation of the mirror surface just like the picture is. It can be used to calculate the width of the defect but not the depth. Thanks for the measurement information. CZ Dale Eason

"Mirror Quality"

Paul Leuba writes: Earlier today I noticed a recent thread on the AstroMart Equipment Forums entitled "Mirror Quality". ZOC was mentioned and then the basic theme of the discussion shifted to the perception that one cannot trust Foucault calculated Strehl and

RMS numbers.

"Trust" is an interesting term to be using; I have to smile at that. I've seen that said, myself. What I would have to ask the individual is what do they actually know by empirical test and how much of the statement is theory. You see, in practice, I would venture to guess that few or none of the individuals making such statements have done any amount of serious testing to make comparisons and find out what differences exist, if any. But we have. We've had our optics tested by many methods, many of whose results have been made public. As I've indicated in the test method agreement articles to date and have demonstrated in several cases, the information generated from our testing on a smooth optic can be quite accurate. Here's an interesting example of an unsolicited test on one of our mirrors.

Not long ago an ad came out on Astromart for a mirror we fabricated some years ago. The seller posted the numbers on our doc, including a Strehl ratio of .998. Well, for some reason that I can't figure out, (after them having used it at well over 50x per inch successfully and knowing it's a superb mirror) the owner of the mirror said right on the ad that they sent it to Torus (now OMI) to be tested by interferometry. Torus came up with a Strehl ratio of .983.

Well, right off the bat the difference is approaching negligible. That's 1.5% difference between two different tests in two different shops. But let's not stop there. You have to take into account some additional factors when comparing results. For one, the internal error in the test cavity of the interferometer, because auxiliary optics are used to create the reference wavefront against which the mirror's wavefront interferes, as well as the nulling optic, being either a flat or a lens. Then beyond that we have the standard bill of fare that affects all testing, such as room currents that didn't get fully averaged out, residual astigmatism that may remain after the averaging process by rotating the mirror, and so on. So the final result given to the mirror will have all those residual errors added in. Those are points that many folks fail to consider, that being the mirror will be saddled with the error of the interferometer itself in the final result. That's a VERY important point. And consider further that the mirror was not made in that shop. That means the test does not have the benefit of being a "self-fulfilling prophecy", as I like to call it. What I mean by that is an accomplished optician can figure a mirror to match the error in their test setup until they get a perfect result *on that system*. But because of any inherent error in that system (which all systems have to some small degree) it will not measure precisely the same on another.

So in short, a mirror from a different shop tested by another method fabricated by a different optician which mirror took on the internal errors of the system during test came out within 1.5% on the Strehl ratio for documentation. Folks, I'd call that a match, wouldn't you? Quite frankly, I'm impressed with that test; it looks to me to be a good one. I'll also note here that in my opinion that mirror had to be damn near perfect to be able to take on those conditions and still come up with that result. And coincidentally, it was measured as essentially perfect in this shop. (No, it must just all be coincidence...).

What we know from our data having had optics tested over the years is that our Strehl ratio is within 1-3% of what a well calibrated interferometer would get as a result, depending on size of mirror, smoothness of figure within our tolerances, and F-ratio. I'll leave it at that for now. While this may generally be true with mass produced optics, I find ZOC mirrors to be the exception. I have owned five ZOC mirrors and think Carl's numbers offer a fair representation of the optic. I think "fair" is a good word. In addition, Carl has always said that the numbers that he generates are for HIS use. Basically, the Foucault generated numbers tell him when its O.K., to stop grinding/figuring/polishing. I believe that he only sends out documentation because the "other guys" (competing manufacturers) do. We used documentation when we were a telescope-making workshop that taught amateurs to make their own telescopes and mirrors. That evolved naturally into more elaborate documentation when we went commercial. However the main reason we continued is because my mentor does. We simply followed in his footsteps as he opened the door for me to his customers, the scope makers. They were used to it, and as far as I know they expected that we do the same. We used the same methodology and documented the same aspects. So go blame my mentor, okay?

Let me share with you a true story... When I took delivery of my Starmaster 14.5 goto/track from Rick back in August of 2003, both Rick and I observed with it for a night at the Black Forest Star Party here in PA. As an aside, let me say that if you ever get the opportunity to spend some time with Rick, jump on it, as it will be time well spent. You'll learn a lot, and not just about Astronomy. While observing the summer Globulars in the Sagittarius region, Rick remarked to me that he never gets tired of looking at objects through Carl's mirrors. And, that if 100 ZOC mirrors (of the same aperture) were lined up it would be impossible to tell the difference! Incidentally that night, the summer globulars and, especially Mars looked particularly nice through my new 14.5". I was a proud Papa -- indeed. Throughout the autumn months, I compared to the views in my Starmaster to other scopes in my informal local observing group. On several occasions, I compared it to a friends' 20" F/5 manufactured by another scope maker. While the view in the 20" F/5 was brighter and the image scale was bigger, the fidelity/integrity of the view was worse. There was definitely something wrong with the 20" mirror that could not be attributed to collimation. Of course this sort of thing is delicate to talk about especially when the owner of the scope is a friend and was standing right there. According to my friend there was no way it could be the actual figure of the optic because he had a manufacturer certified interferometer report. So we chalked it up to being a problem with the enhanced coatings. I have heard (on this list) that it’s very difficult to apply enhanced coatings evenly across the optic... My friend sends the mirror back to the manufacturer for a recoating. About a week later he gets an email from the optician. The email basically said that in a routine inspection, "...we found a turned down edge and the surface is not as smooth as we are making them now". So, the optician offered to refigure the mirror at no charge...

Nice gesture, but give me a break! This optic should have never made it out of the shop! So, go figure (excuse the pun)! As far as I know, the interferometer data sheet showed NO indication of a turned down edge. Either the original interferometer report was forged or the optician is not skilled in the art, methods, and use of an interferometer. In either

case the data sheet is not worth the paper it was printed upon. This is not the first time I have heard about problems with interferometer data sheets. I think its far more common to ship tenth-wave interferrograms with quarter-wave mirrors then to send out doctored up Foucault test results.

One last piece or irony... I was observing last night (Saturday) with my friend who owned the 20" F/5. He has since sold the scope and purchased a used Starmaster 16" w/ Foucault tested Zambuto mirror off of AstroMart. I would like to say concerning the manufacturer in question, on their behalf- they did make the offer to refigure the mirror and apparently did so, and that is a positive thing. I hope things go better for them in their future, which future is of course, up to them. You know, Paul, your story really puts the "real numbers as opposed to dreamed up" description in a whole different light. But people are going to believe what they want to believe for their own reasons. It always seems to work that way. An aside, you know something that gets to me about all this? Some very people who say that method of documentation is more valid, by doing what you have described above are doing damage to the method itself. They're giving the TEST METHOD a bad reputation! I don't necessarily appreciate that. Interferometry, as well as all established methods of measurement to me is sacred art, and they should be used as such. It goes back to that covenant described by Jack Semura.

Okay, well thanks for the story. You had guts to tell it. Most people don't tell such stories in public and that has consequences. What we know to be so is that story is not isolated. It has happened many, many times over the recent past, but we don't hear about it in every case. In fact, the majority of the cases are never mentioned in any forum. It appears what people are doing is quietly solving their problems in whatever way they can, all the while saying little or nothing in public. The result is, well, you know how the saying goes, that we get what we deserve? If the amateur astronomy community does not police itself, no one else is going to. If the amateur astronomers in this country don't take care of each other and inform each other, how are you all going to know what is going on? -Yes, yes, I know we have to be politically correct. Well, fine. That too comes with a price. My next posting will also be about documentation- ours. We have a small announcement to make. Going to stop the controversy all together (as far as our stuff goes) and concentrate on what is important. We call it performance. I expect to get the announcement and a copy of the new cert out by the weekend. CZ

Interferometry

Steve, I think your points are worth discussing, it is an important subject. Here are my thoughts and opinions, and some of my experience: During fabrication, typically another method of test is used. Opticians don't usually fabricate amateur mirrors with interferometers; they are used for final documentation. And during fabrication with any other methods, (no matter which they are) all those conditions show up, all of them. A mirror should never go out of a shop with a high-90's Strehl ratio rating on its doc that admittedly needs to be refigured. That is irresponsible documentation, in my book. Judge it how you like, I see no other conclusion to come to other than what Paul suggested. Let me clarify here that we're not talking about mildly rough surfaces and narrow turned

edges. That's understating the issue, in cases that I'm aware of. And I'm aware of a lot of them. I have had mirrors in this shop on my bench whose interferometry reports said the optic was 98 or 99%. They measured with strong spherical aberration overcorrected such as 1/3 wave, that by itself is enough. But they also had rough surfaces and wide turned edges, between 1/4 and 1/2 inch, as well as central depressions that were larger than the central hole in any test flat. How can a responsible optician put such a rating on such an optic? Furthermore, Strehl ratios as estimated at around .4 by the knifedge plots were horrible. This is not from just one or two mirrors. Between customers talking to me, reports by our telescope makers from field-testing, me being at star parties looking through mirrors myself, and having mirrors on my bench, there have been scores of them out there. I fully agree with Paul. I don't know the cause of the action, and to me it doesn't matter, the result is the same.

The point is that it exists and there is no justifiable excuse for it. Those mirrors I saw were very poor quality. And from what we can tell, there are still many of them in existence. It should also be pointed out here that turned edges show up just fine on an interferometer as well. The fringe goes to the edge of the mirror. A static fringe will show a turned edge quite well, the fringe hooks just like a Ronchi band. Roland Christen demonstrated this clearly some time back, in response to this very subject. He posted public photos as I recall. Note here that it is possible to occult the edge of a mirror during test. There are many ways to do it. Bottom line, I think what Paul was saying is that you don't put a premium Strehl ratio rating on a mirror that admittedly needs to be refigured. I agree with him. I see nothing unfair about what is being said. In fact, I see it the other way around. I have personally watched many amateur astronomers go through all kinds of frustration, in shock over what happened to them. *That* is unfair, as I see it.

They purchased something believing what they were told, and it was not so. Steve, as professionals, there are a half dozen of us who have looked at this issue of documentation and how it is being done. We know things at a glance in cases that the amateur simply cannot recognize, because they don't have the fabrication and bench experience. And I assure you; it is in our interest to do so, that is, to know what is going on in fact, as opposed to what any public rhetoric may be. We as professionals can look at a body of documentation and see right away if there are inconsistencies. There is more to this story than meets the eye, but I'm not going to speak to it because it’s not relevant at this time, nor am I interested in pursuing this subject any further. Frankly I don't like this subject. I've made an attempt in the past to prompt you in your ongoing research on these matters, because I know you love this stuff. You probably eat it for breakfast :)

Recall when I made some specific suggestions about how to find out what you have with your mirror. I was going somewhere with that. Recall also that I've stated unequivocally that the knifedge will always give a better result than an interferometer. I was going somewhere with that, as well. These things would have led to a greater understanding about how this whole thing works. I was attempting to prompt you to places where you could make some better-informed conclusions. You said yourself you wanted to get to the bottom of this. My advice, if I were asked to give any, is to keep a totally open mind, and to gain knowledge from multiple sources. A narrow view does not show the whole

picture. I guess that's all I have to say about the subject. Personally, I'm happy to leave it and go on. Instead of all this controversy, my wish is to withdraw from numbers for documentation all together, and we're in the process of setting that example. Will expand on that shortly. Thank you for your posting. Carl

In zambutomirrorgroup@yahoogroups.com, "Stephen C. Koehler" wrote: At the risk of getting flamed, I have to say that I think the recent discussion of interferometry by some members this group has been very unfair, in particular the insinuations that the maker of the 20" mirror either faked the numbers, or was incompetent. People have been making the assumption that interferometry is capable of detecting turned edge and roughness. First, there are different kinds of interferometry. The most sophisticated version (phase shifting interferometry) is not yet being used by mirror makers for the amateur market. PSI is an order of magnitude more precise than static fringe interferometry. Properly done, static fringe interferometry is a step ahead of knife-edge testing for capturing the basic figure of an optic and for assessing astigmatism. It is not precise enough, however to detect roughness or a narrow turned edge. I think it is useful to think of static fringe interferometry as a direct replacement for the knife-edge test in the mirror making process. It provides a final check on the mirror's figure, but is not the final say about a mirrors quality. What leads to a quality mirror is good process (as Carl has repeatedly said). It is good process that results in a smooth optic, and eliminates turned edge and roughness. Final interferometric certification will not do that, and consumers should not expect it to. I agree with the sentiment that interferometry should not be over sold as a solution to all optical problems. It is clearly not that. In the end, what count is consistent results from the optical shop and a willingness to address problems that show up. -- Steve Koehler koehler@s...

Mirror Documentation

Hi again, everyone this has been a long time coming. Maybe two years. I realized a long time ago that documentation could create problems. There was a time when the information that we have supplied since our very first mirror was all that was available for any optic. Everyone went by the Texereau standard. The beauty of that simple information is anyone could have it verified by anyone who had a bit of experience with a Foucault tester. Almost every astronomy club has someone who can do that. There are four reasons listed on our explanation page accompanying our former documentation as to why we supplied the measurement information.

There is also a fifth reason, one I have never mentioned outside of this shop. The documentation had a way of keeping me honest to a fault. I knew that at any point in time anybody could throw a mirror on the bench and absolutely verify what was on that paper, because every parameter of our test is on that sheet. The entire test is laid out on that paper and is fully reproducible by any amateur mirror maker or tester. It was a way of policing myself, through thick and thin, regardless of how things were going, or how I felt, or how behind our schedule was, or how the bank account was doing. And every time I took a final measurement that fact was always standing over my shoulder. By now we've done so many mirrors that I'm well trained. It is habit now, one I don't seem to be

able to break. So I guess it worked, because every time somebody has done a measurement on our mirrors by same method and compared it to our doc, to our knowledge their averaged measurement has never deviated more than 1/50 at the wavefront.

It is with some sadness that we say goodbye to our printed numbers. I have always been proud of this aspect of our work. What it does is it displays right in front of God and everybody each nuance of the surface of the mirror, which is a direct result of the strokes done during the figuring process. Those graphs are artwork, pure and simple. Each one is a little different, each one unique, but all within a particular tolerance. Those graphs are Zambuto Optical Company. They are the final result, as far as something that can be printed. Our real intention in supplying the numbers from day one was to inform (I was kidding when I blamed my mentor). A part of what I've always done has been about information. I wanted to provide as much information as reasonably possible to everyone involved to satisfy as many as I could. There was a time when it was more useful to more people. I've been accused of being from the old school; I'm guilty as charged. The days of the old school are disappearing in the distance. Technology has brought new methods of documentation to the industry, and things have changed. I've finally realized that we need to change with it. I would say that everyone reading this knows full well about the controversy that can and does surround methods of testing and documentation. I've been watching it too. It has affected us, to be certain. The bottom line here and what I'm getting to is this.

In my opinion, our documentation has come to the point where it is doing more harm than good. There are many reasons why I say that, and perhaps right now I won't get into the details (If anyone wants to discuss that aspect further don't hesitate to ask, I'm happy to discuss this subject thoroughly). Instead, the time has come to follow in the footsteps of those who have gone before us. I believe Roland Christen used to supply data, and he no longer does. He keeps it on file, same with Thomas Back. I've also had discussions with veterans whom I respect greatly, such as Al Nagler and Dick Suiter on this subject. Their advice is the same. What we're going to do is simple. We're going to make the same guarantee we always have. We're going to make the same mirror we always have (in fact they're slightly smoother yet again, generally, overall). We're just going to stop printing measurement information. It will be on file just as it always has been. We keep every measurement that takes place on each mirror, from the first to the last. We have a complete history of the figuring of every optic we do. We're simply going to keep it here now, for reference. And we're going to do one additional thing, and that is keeping an image on file for every mirror, which will be an absolute identifier for authentication.

On Jan 1, 2003 we began imaging the serial numbers on every mirror that went out of the shop. We have high-resolution images of every mirror since then. Those images are irrefutable identifiers of authenticity of the optic, in the case of any kind of a dispute. So that's the deal: Same mirror, same guarantee, we're just going to keep things simpler. No more arguments over Strehl ratios, or this method vs. that method, and etc. Instead the focus is going to be on performance at the eyepiece. The guarantee is a performance guarantee, it always has been. So really nothing changes. The fact is people buy a mirror

based on reputation. The paperwork is a crutch of sorts, an extra prop. But people don't buy mirrors because of paperwork. They usually spend some time finding out about the reputation of the mirror maker...at least I hope they do. I do believe that is the case, in our case. And from now on, that is going to have to be the case, because we don't support selling mirrors with numbers, and as is evidenced by this change, we won't be participating in any fashion in that sense, again. The new certificates (I can no longer call them documentation) have already begun shipping. Starmaster is receiving the first ones. I'll introduce the certificate itself to everybody here on the mirror group shortly, in my next posting, as I want to explain a little bit about it when I do (this posting is long enough already...). Cheers, everyone. CZ

New Interferometry Discussion Group formed at Yahoo

Cool! Thank you, Scott. Will drop by and take a look. I'm also looking forward to the day when Bill Zmek's book comes out. Don't know when that will be at this time, but I know he's working hard on it. Carl I thought that with all the recent interest in optical test methods demonstrated in this group, some of you might be interested to know (if you don't already) that a relatively new discussion group has formed on Yahoo, focusing (pun intended) on the design, construction, and use of interferometers (and associated software) for optical testing. If interested, do a search on the keyword "interferometry", and also please try to remember that this particular group has not been a forum for debating the relative merits of the different test techniques, but rather has focused on getting the rust off the nuts & bolts of interferometry. Scott Milligan

Accuracy of Foucault Testing

Alan, Welcome to the fray. The reason the subject is misunderstood is the terms are not defined. People are comparing results from different methods of test which are *in fact* apples and oranges. If one adequately defines what a wave is as it applies to the rating on a mirror, the whole thing becomes more straightforward. At that point I can probably give you some pretty good data on what the test can and can't do. If you have the desire to stick with this, it could become a good discussion. And you may come away with a little more than you bargained for. What will likely happen is this will also dovetail right into part three of test method agreement. And I'm much more fond of participants driving this thing with well thought-out questions than myself just dumping information out there. I don't get paid enough to do that. So if you're game, a good place to start might be here- what do you mean for example, by a "1/10 wave mirror"? How is that defined and by what method is that number derived? CZ

Michael Thanks. Robert Sager had already pointed me to this message on the Astromart Equipment forum. It talks about Texereau's theoretical analysis, which is fine, and is echoed by Malacara in "Optical Shop Testing." My question is not on the theory, but on how we know what accuracy is achievable in the real word by people doing the test. Post #501 points to some accuracy claims by mirror makers, but how do we know these relate to reality? Some experienced testers claim the test is good to 1/50th wave, yet others say

numbers exceeding 1/10th wave do not reflect reality. I am sure both sides have some basis for their view. I'm uncomfortable with having this as a matter of which side to believe. How do I know which view is correct? Clear skies, Alan

Very well, Steve understood. Thank you for your reply. Carl

Carl, I've made an attempt in the past to prompt you in your ongoing research on these matters, because I know you love this stuff. You probably eat it for breakfast :) ... and lunch and dinner :-) <snip Thanks for all the time and effort over the last year you have spent answering my questions and coaching me. I really appreciate it. -- Steve Koehler koehler@s...

One more point. Texereau was a *fabricator*. His work was real world. If somebody truly understands his work they will know that it is correct. But how do you do that? As I look at this subject of theory and practice, and what is "real" and what is not, I'm struck again and again at the gap that exists between amateurs and professionals. As an amateur mirror maker of many years ago I always wondered why that gap existed, but now I know, because I'm now standing in the other place. I see it as clear as a summer day. The person who does this stuff day-in and day-out whose livelihood depends on it, has a perspective that the amateur simply cannot have, and will never have. The gap is created by one thing and one thing only- fabrication experience. And try as I may, there is no way to impart that knowledge to somebody else because it can't be done. It simply cannot be done! Over 1,000 finished mirrors is the difference between one who doesn't do this every day and myself. And amateurs fail to recognize that in many cases. To the person who doesn't have the fabrication experience, stuff they don't have intimate knowledge of is just theory. That's what I hear in your words. But to me it is reality, because I see it happen day after day, and it always happens the same way. I KNOW what this test can do.

And the other very interesting thing that I notice is the greater the mastery of a particular individual, the greater agreement they will have with every other master, because they always come to the same conclusions. When I attended the optical shop of Bob Goff I was struck with the similarities in how we did things, many of which I had come to independently. And I'm also struck by the fact that the more mastery that we achieve here, the more we seem to be doing things the way I witnessed in the shop of Robert Goff! It is the fabrication experience that separates the theory from the practice. And we're privileged to know which is which, because we paid for that knowledge, the hard way. Texereau was one of those guys, as well. CZ

Alan, Robert Thanks for your replies. Alan, what I'm reading is your precise question is how well a Foucault test can determine the *entire* surface of the mirror, and how close of a representation it can actually be of "reality" (whatever that is). Before I do more work on the subject, is that what you're after? I'm going to take a short break from this thread and try to post the certificate. Will get back to you soon, as we can talk about test methods over time, for as long as you like. Carl

I have been told this before by a manufacture. This mirror is produced to a standard of 1/10 wave. No other information was given. My idea of 1/10 wave would be the plot of knife-edge readings vs. mirror radius with the 1/10 wave envelope around the theoretical perfect parabola and all the readings falling in between the 1/10 wave envelope of either under or overcorrected. Robert

Carl, Thanks, I appreciate the offer. When I say 1/10th wave mirror, I am talking about PTV at the wavefront derived from a knife-edge test. I understand that it can be misleading. A mirror can have a small, local error of 1/4 wave, yet be smoother on the whole than another 1/10th wave PTV mirror, and the RMS value or Strehl are better ways to rate a mirror. When a mirror is tested using a knife-edge, the tester measures a number of zones across one or two diameters. The analysis assumes these zones are representative of the mirror across the diameter or diameters. When folks generate RMS (or Strehl) from Foucault readings, they further make the assumption that the mirror is symmetrical, and the diameter is representative of the mirror as a whole. I wonder if this is a reasonable assumption. It is probably more reasonable for folks like yourself who have many, many mirrors under your belt, than it is for the average ATM mirror maker. Clear skies, Alan

Alan, if you haven't already, I might suggest reading parts one and two on test method agreement. You might find some interesting examples in there that will give you some added perspective on the subject of Foucault accuracy. Extrapolating the test over the entire surface is obviously an assumption, to a point. The rougher the surface of the mirror, the less accurate that extrapolation is going to be also, obviously. I don't have any graphs to provide, we just keep our mirrors as smooth and as good a figure of revolution as we're able. However, over time we've developed techniques that we can use to learn how regular a mirror is, which can provide some indication.

One of the things that are very interesting is to compare plot overlays between axes. We use this primarily as a check for astigmatism, but it tells other things about the test as well, one of which is the repeatability of the knifedge. In the files section go to the folder "test method agreement". In that folder take a look at "10inchmirroroverlay". What you see there are four 10" F/5 mirrors from a production run. The graphs are our typical check for astigmatism, as each has two sets of plots, one orange and one blue. The two sets were taken at 90° apart over the surface. Note the vertical scale on the graph; one line represents one hundredth on the knifedge, which means there are ten thousandths between each line. See how uniformly the plots overlay. This is a testament to two things with reference to the situation.

One, the mirrors are superb figures of revolution in those two axes, but observe also how the test repeated! Note the center is always the most difficult to measure. There may be very slight astigmatism in the center, or it may be measurement error of a couple of thousandths in the center zones. But what you see otherwise is the ability of the test to reliable measure (under good conditions) to plus and minus 1/1000 on the knifedge! It is for this reason that we have found mirrors such as these to be very close in Strehl ratio to what a well-calibrated interferometer will say in a good test. I would say these mirrors

would rate within from zero to 1% of the interferometer, provided the edge is good. At the same time, as mirrors get larger and faster, there is more room on that Pyrex for deviations that a Foucault test can't quantify, but can recognize.

Example, what happens in local deviations is in the plot overlay you will see one zone deviate by itself, when the others do not. That indicates a localized error, and will promote a reduction in Strehl ratio. For an example of a minor deviation in the same folder see "Foucault overlay" and look at the top graph of a 12.5" mirror at F/4.5. Most of the plots match up rather well, with the center one missing a bit. The fact that the center and edge match up shows there is no primary astigmatism in the mirror, but there is that localized error around the 50% zone, albeit a small one. So the test itself is extremely capable, as Texereau and Malacara have indicated. The functional limitations will be the quality of the piece under test, and the operator. How repeatable is it between operators? Many have compared measurements with our docs over the years. Gery Seronik and myself measure very close together. We did a 10" that was almost as close as what you see on those 10" graphs, save one zone. Bob Kirschenman has measured a smaller mirror to about 1/250 wave of our doc. Bob Goff has measured several of our mirrors, having said our 10's were 1/20 wave or better for spherical aberration (which is what the knifedge test measures). If you look at how much wiggle room there is between 1/20 wave and perfection, knowing that our tolerance on those 10's was 1/20 wave, one can deduce that Bob and myself measured pretty darn close. There are more, I don't remember them all. But to put it generally, my experience is that any reasonably experienced operator will come within about 1/50 PV wavefront of our doc for spherical aberration. And I've also found that the more experienced an operator is, the closer we will measure to each other.

One interesting example is a measurement of a 12.5" F/4.5 done in Florida by a mirror-making group. On that same file "Foucault overlay" see the middle graph. The blue set is our documented measurement. The orange set is interesting. Five ATM's of unknown capability (to myself) took turns measuring the mirror wherein each one took one pass. They combined the five measurements and used that as their result. Notice that beginning from center they start below our plot, then above it, then below it, and, etc. Finally at the edge they stabilize. That is a pattern for poorer measurement and we do the same thing. A worse test will deviate randomly. When I'm measuring poorly, I get the same effect. So between the two plot sets there are obviously deviations, but I do note that both sets will fit in the M-L envelope. And as far as the wavefront profile goes, the difference was no more than 1/70 PV between the two sets. So that gives you another data point for repeatability. Understand that the knifedge measures spherical aberration. And that it does very well. I find that we can measure up to about 1/50 wave spherical, and after that it begins to "float". The fact that most operators can get within 1/50 wavefront plus and minus of our doc, says that number is about where it ends. So I would say to you the accuracy of the spherical component approaches about 1/50 wavefront PV, and blurs out between there and 1/100 wave. I don't know how much of your question has been answered. If you need more specifics, let me know. This is a big subject, to be certain. Carl

Carl, Yes, that what I am interested in, particularly the issue of extrapolating the Foucault readings to the entire surface. I know reality can be tough to pin down. Other tests that might be used for comparison have their own limitation. Perhaps it would be better to ask how repeatable the test is between experienced testers. Thanks again. Clear skies, Alan

Yes, the term "reasonable" is probably a good one. At the same time I don't want to oversimplify the subject. We can't say that any ATM can take a set of measurements and know their mirror will have a Strehl ratio close to a good interferometer. It's not that simple as there are so many variables involved. But it's worth discussing, because it's an important subject, especially for the ATM. When you want to continue with "measurement vs. reality" again, just let us know. We can all explore it further. If I ever get to part III on test method agreement we're going to compare Foucault with an interferogram (phaseshift10) in more detail. That will give more perspective. Perhaps I'll get back on it when you continue our discussion. Right now we have parents from out of town and I need a short break. May be out for a few days. Carl

Carl Thanks. Pointing out the two messages and such saved me a lot of rummaging around - not that I won't rummage some - and you gave me a lot to mull over. It sounds like your methodology makes extrapolation from Foucault readings to the entire mirror reasonable. You've got me thinking about dusting off my Foucault tester and that polished 8" f/7 that's squirreled away downstairs. I may want to return to the "measurements versus reality" question, but not without giving it a bit more thought. Clear skies, Alan

Interferometry and a Mote of Dust (OK - Fleck of Paint)

You know, Michael, in the past I have said to folks many times that an amateur mirror maker could have gone in there with a Foucault tester and found the whole thing as all wrong. The Foucault test in my estimation is highly underrated. Its funny now to be able to read today that somebody went in there and actually did a knifedge test on the Hubble mirror and found the mirror was out. How ironic. The whole fiasco was a case of technical arrogance. The formula is simple= r^2/R defines the knifedge shift (for a paraboloid). The radius of curvature is the radius of curvature is the radius of curvature. Each place on the mirror should be in a particular position as described by its conic, and either it is there or it is not. It is so easy to find and so deadly accurate on a smooth surface. How absurd that a Foucault operator could make the report and no attention be paid to it. Reminds me of some folks in the amateur industry. Must be "subjective and meaningless" I guess. Maybe what we need are more opticians from the "old school". CZ

In zambutomirrorgroup@yahoogroups.com, "Michael Gilbreath" wrote: Hi folks, If you want to enjoy a really interesting read I highly recommend this thread by Bill Jefferys (I copied it to this group below): <great big snip...

New Certification Coming on line (Official Announcement)

Dearest Jeff, God bless you, I appreciate your sentiments. There is a lot going on out there on many other forums. People are confused over what is right and what is not. People are arguing over who is credible and who is not. People are taking shots at us in many ways; some are innuendo, and some are outright overt. And as a result many people are just flat out confused. It has been going on for years. I tire of the controversy, and in fact there is no real need for it. The explanation I gave earlier is the reasons why, and I will be posting the text of our addendum sheet soon, which will restate why we're doing what we're doing. The numbers are not wrong. They're just not absolutely necessary, and as I think I said before, in our judgment in the larger picture it appears to me they are now doing more harm than good.

BTW, there is still going to be a certificate, which I'm going to put up in the files section as soon as I get done with all these posts! Understand, Jeff that this is not because of everybody. You know how the saying goes, what a few apples can do to the whole barrel. That is the case here. Let me cite one example for you, because you don't read other forums. There is a reputable long-time telescope maker who says to their customers that our data (they infer us) is "dreamed up". You can read it penned by their hand right on their Yahoo group. And in private they tell their customers that our measurements are "subjective and meaningless".

I have that in writing. I'm going to take that away from them, Jeff. The only thing they seem to be able to attack is the credibility of our documentation. They're not going to have that any more. I want to remove myself from the controversy so we can focus on what is important. It is not the numbers. The numbers don't tell you what you're going to see at the eyepiece. They don't have that capability. For those who have been following developments in the larger community in the last few years, it has been proven many times over that regardless of method of test, the documentation cannot guarantee what you will see at the eyepiece. But don't think I'm giving up, because I'm not. There are two edges to this sword. This change has ramifications to be sure, but note that two of them are this: One, there is nothing left to shoot at. And two, now the shift in attention will be brought to the eyepiece, where you and I know it really matters. There is going to be no more discussion about what numbers are right and what numbers are wrong. There is going to be no more argument over whose test is better. (Its not about tests, its about opticians, anyway).

Let them try to outperform us in the field. They can put out all the data they want. They can print page after page of documentation. But if they want to compete with us, they're going to have to do it side by side in the field, at the eyepiece. Oh, and another thing it does, it levels the playing field, and quite simply. I think that's a positive thing. I'm not "above the swirl", Jeff. I'm right in the middle of it, and I "feel" every time somebody takes a shot at us. I've had enough of it. I want our customers to not have to argue any more. I don't want our customers to have to defend a test method any longer in forums where people who have never made a mirror command a discussion group because they have more time to spend at the keyboard than everyone else and possibly nothing better to do. What I want them to be able to do is put the numbers away and say as Geoff and Barry have said, "take a look here, in the eyepiece". Thanks for your concern, and I

appreciate that you voiced it. I'm really glad to have you for a customer. Carl

Hey Carl, I am not privy to what's going on as I only subscribe to this group. Something must be going on to anger you. Something must have made you decide that we, the public at large, simply are unable to use the docs you provide in an objective and responsible manner. I am a bit 'disappointed' only in that I got the impression you are 'above' all the swirl and really didn't care what others thought of your methods, docs, or numbers. Truly, the performance of your mirrors speaks for themselves. So why not continue giving the numbers? The images bear them out... I guess I am curious who in the right mind could possibly question your reputation, integrity, and the results of your labor, to the point you decide the world simply is not ready for your docs/numbers? I'd really like to know who these.... what is a gentleman's way of putting it??... Fools? Detractors?... <expletive deleted people are? Your work -does- speaks for itself. So yes... you can go the way of Roland and your work will still be in high demand. (BTW: Al has nothing to brag about in the ocular area as bad Naglers, Radians, and Panoptics have, in the past, made it past of Televue QA. I have a bad 16mm Nagler to prove it. Different kind of business of course.) You must have felt in the past the docs for each mirror were correct and worth giving out. What or who convinced you that was wrong? That really is more telling than the actual change. As I said, ZOC mirrors will still be in high demand. But it is as if something, some trust -you- had with us, not us with you, has been lost. Best wishes, Jeff

ZOC Mirror Performance Guarantee and Authentication.

In the files section is a full size copy of our new certificate. What is it? It is a statement of Performance Guarantee and Authentication. Our guarantee of performance (that we have used since "day one" is stated), the method of authentication is indicated and it is dated and signed by "yours truly". Now about the format, I spent a lot of time considering how we were going to do that. I wondered how we should make the page "look". Do we want a standard certificate template with gold embossed borders? I looked at a lot of certificate templates, some of them very nice ones. They didn't ring any bells. Then I thought about an astronomy theme. The idea hit me that we should put a backdrop of an astrophoto taken through one of our mirrors, and uses that. I saw a lot of stationery in stores that had picture themes that were de-saturated in hue so you could print right over them without interference. So I did that. I took a couple of nice astrophotos our customers have sent us and set them up as a template. They look very nice, and we have those on file. But then another idea altogether, hit me. I asked myself what is it that we're trying to say? And from where does the authority come? The answer came to me quite clearly.

The answer is, the reputation belongs to the optician who signs the document. So that leads to (embarrassingly), a portrait of the optician actually doing the work. And why is that, you ask? Well, the way I see it is this certificate makes a statement. When you hold this thing in your hand it says something to you. You have the name of the company, the statement of guarantee, the signature of the guarantor, the title of the guarantor, and a picture of that individual right in front of you. The person on that paper is making that statement and that guarantee. I see it as rather personal, like I'm making that guarantee directly to you, and that's how I want it to come across. Before we made the decision to

go online with the new cert it was shown to the telescope makers and I got their feedback. Other than that fact that I'm not a supermodel, they thought we could scrape by. The certificate is heavyweight matte photographic paper, so it is solid stock. The photo takes a full 12 minutes to print, so they are seamless (The print quality of the photo is superb). The image in the files section is a scan of an actual cert. So for the time being that is what we're going to use.

Questions and comments are welcome. In the files section find a folder titled "New Certification". In it is an actual size jpeg of the certificate, and a text file of the addendum that accompanies the cert, explaining about standards and tolerances, and about certification in general and why we're doing what we're doing. Cheers, everybody! CZ

Measurements

John, The answer is yes. I haven't said this yet, because I want our new approach to take effect, but since you asked I'll be candid about this, now. You picked up on my statement in the addendum that was put there purposely to leave that door open. I haven't decided the precise criteria as yet, but if somebody who recognizes the value of the measurements we make requests the final measurements for one of our mirrors, I'm inclined to provide them. The main idea is for those who want to use them for reference in measuring the mirror or having it measured. Let me give you an example: If an ATM or someone who measures mirrors has a desire to perform a knifedge test or have it tested by same method, I'm inclined to provide our measurements privately, for reference. This comes under the heading of learning and education. I'm a sucker for ATMing, as I was once an ATM myself. (I sometimes wish I could once again be an amateur. There was a lot of freedom in that). I would have loved to have measured a mirror made by someone with a respected reputation and have his or her measurements to use as a reference.

I did that with my mentor on an occasion. I measured a mirror he made and had his data with me at the same time. We came within 1/50 on the wavefront of each other. So in the spirit of education I might be willing to provide the parameters and final measurement. Now note that I did not say I would reduce the data. The reason for this is as soon as we print out the reduced data folks are posting the numbers in public forums and on Astromart, for one reason, to resell mirrors. I made a request in the addendum on the former docs that whenever one posts in public they always indicate how those numbers were derived. I don't think I've ever seen it done one time. They are stated as fact, and that puts a "bulls eye" on my chest, as Richard has pointed out. So I want to be very careful in my answer, and not make it an unequivocal "yes".

I wish to be allowed the room to make policy changes on that issue as I see fit. But if you come to me and have a good enough reason, I probably won't deny you the final measurements on a mirror. (My druthers are that you would say to me that you're going to have a club member measure your mirror, or that you're learning to do it yourself.) If you want to reduce that data yourself, you can, but I won't print that on paper. You'll get the zone parameters, the other critical information and the raw measurements, which can be plugged into any data reduction program. How that is interpreted is up to each

individual, so they can no longer say "Zambuto says the mirror is x-wavefront". I have not requested a non-disclosure agreement to date, and I don't think I will. This issue is not that paramount, as there are already a lot of docs out there and I can't change that. I know my answer seems a bit nebulous, because I need some time to sort this aspect out. I don't want to squash education. The aim is to reduce confusion and controversy. Thank you for asking. Carl

Mr., Zambuto, I'm sorry if that sounds too formal, but I can't bring myself to call you Carl without having had some prior contact with you. :) I do not currently own a ZOC mirror, but I hope to do so someday. As a potential customer, I'd like to ask you a question. I note in your addendum, you state, "The one difference now is we're no longer printing those measurements on the certificate. If you have further questions about your mirror, you're welcome to contact us." That coupled with your stated reasons for making this change has me wondering if this possibly implies that the owner of a mirror could request a copy of those measurements, perhaps provided that they would be willing to agree to a non-disclosure agreement? In this way the owner could get the data if desired and this would also satisfy your (quite understandable) desire to avoid a meaningless public "numbers" contest/dispute/etc. Regards, John

New mirror certificate

Jim, I'm so pleased you brought this subject up. Its a good subject and in my estimation, worthy of discussion. It is natural for some folks to consider that what we did was because we were about to change our standards to the downside. Given human nature, it is not an unusual assumption. History will be the judge as to what actually took place. In light of these kinds of thoughts going around, I wish to say here that I appreciate all those steadfast and appreciative folks whose trust we have gained over the years, and who understand our commitment to quality. Their trust is not misplaced. I want to answer this subject in detail, I'll write about it shortly, as I've been thinking about it a lot of recent. For now I'll make a short statement. Our history has been to always improve the product in every reasonable way possible. We're making the best mirrors we have ever made, *right now*. When I explain why, it may well generate some discussion, and I expect will cause some serious doubt and disbelief, because it is frankly backward from the typical thinking regarding documentation. I've uploaded six ML graphs from the last six mirrors we have just shipped. Go to the Files section, New Certification Folder. The document is "***6MLgraphs***". Three are 11" F/4.5's and three are 12.5" F/4.5. The vast majority of the plots are touching the line. The measured peak to valley spherical aberration all have such numbers as I would not want to document for fear of more disbelief and ridicule than we used to receive in the past. The "pedigreed" ones on average were not precisely as accurate as what we're doing now, today. I really don't care that no one will ever know how accurate these mirrors are. What I care about is my work and my standards, and I care about the performance of the product that goes out this door. The folks who have those earlier pedigreed mirrors can boast all they like, but they're not going to outperform our current production. (In truth you still will not see any difference at the eyepiece in focus on any of them).

We made the certification change precisely for all the reasons I said when I made the

announcement, and for one more reason that I did not say. Now that the subject has been brought up, I'm going to write about that reason in detail. Its really rather funny, as I think about it. Thanks for your posting, Jim. CZ

PS, as far as the collectability of the old certs, let me assure you, many folks misplace and lose them. It is common for me to receive requests for copies of a cert about the time when someone wants to sell a mirror, or when someone wants to buy one. I get requests from both buyers and sellers frequently, because the seller lost the cert. Once folks see the true capability of the performance, they frankly forget about the papers.

Hello all, I went back and reread some of the earliest posts on this group. We all pretty much agreed that this was not to be a forum for comparing the numbers on our certificates, but rather a place to learn and share about the mirror-maker's art. The success of this stated intention is ongoing and obvious. So now Carl isn't putting the numbers on his certificates any more. Why? Because he can! I had two minor concerns when Carl made this announcement. One was that the "old certificate" mirrors would become more "collectible" for reasons other than performance at the eyepiece; the other was that some might conclude that Carl's standards had changed. Well, since Carl's announcement, I've seen only two posts (on other forums) along those lines. One boasted that he was getting one of the last "number pedigree" mirrors; I certainly hope he spends more time looking at the stars than his pedigree. (And if my scope is now more valuable because of its "number pedigree", that will be a pleasant surprise for my heirs ;^) The other post suggested that perhaps Carl was about to loosen his standards in order to increase production. This is patently ridiculous to me, and to most all members of this group, I think. And if someone chooses to give up his place in the line, I'll bet it gets filled PDQ! As I noted in my first post on this group, nobody has ever asked to look at my mirror's "pedigree"...but *everybody* wants to look through my scope! Again, Carl is doing this because he can. His most valuable asset-- his reputation--makes this possible. He may tinker with his certificates, but never with his standards, I'm sure! Clear skies, Jim

When we made the certification change, I stated the functional reasons why, that affect our customers. There was also one more reason that affects in-house operations that I did not mention. Since someone has brought up the subject of certification and potential standards change, I would like to talk about that one reason, because it is indeed interesting. It is indeed about a change in standards, but not a change that most would expect. The absence of numerical documentation has given us a newfound freedom, but it isn't for the typical reasons that a mistrusting individual would think. For a long time there was controversy surrounding our accuracy claims. Our spherical aberration peak to valley accuracy numbers was just that- spherical aberration peak to valley, and that is a subject by itself. Right now I want to muse a bit over mastery of the process, and accuracy.

I told a story a while back about conversing with Bob Goff at RTMC some years ago regarding that fact that he had tested two of our mirrors. He had mentioned it in passing as somehow the subject came up, and when I learned of his tests I obviously wanted to know what he found. He said something like, "they were high in the center, then went

overcorrected in the 50% zone, then under corrected again toward the 70% zone, and so on, to the edge. Another way to say it is, they went up, then down, then up, then down (referring to above and below the line that is the parabola on a graph) several times from the center to the edge. I thought that was a strange description, although from a meticulous tester would certainly be accurate. So then I asked him, "Well, so how accurate overall were they?" to which he replied they were both 1/20 wave mirrors. Regarding the accuracy, I knew exactly what he has saying as we were both talking the same language. So given the 1/20 wave comment, I was relieved, and smiled and said the reason the line goes up then down is about the way we process mirrors. It has to do with the method of measurement we use and the subsequent way we employ our technique as a result of the measurement, one zone at a time. The rest of the description, the up and down part, I wrote off as a joke. I mean, who criticizes 1/20-wavefront mirrors? The answer is, Bob Goff did.

What I realize now is, he was teaching me something. One thing I realize a good teacher does is they have the ability to go precisely to where the student is, no matter what level, and push them on from there. If the student has coarse problems and for example is a beginner, the teacher has the ability to teach the big issues at that level. If a student is advanced the teacher focuses in on the fine points, starting from the most important at that level. I now understand Bob was pointing out to me in a not so subtle way that the next level in my work was to smooth out the 1/20 wavefront (1/40 wave surface) dips and valleys on the glass. How absurd, or so I thought. When I was in his shop some years later I noticed a graph paper that had a Millies-Lacroix envelope hand-drawn on it. I noticed how tight it was at a fast f/ratio and asked him about the tolerance. He said the tolerance for that mirror was 1/40 wavefront, or that is what he used as a standard to do the work on that piece. Again, in my mind I thought, "how absurd". And why? And even more so... HOW? Which brings me to my thought. One of the problems I began to encounter on a regular basis in the last year or two was we have been getting the mirrors very accurate by our measurement, especially the smaller and medium ones. We're learning how to smooth out more and more of those 1/20 wavefront bumps, which when measured in RTA, show more as slope error than as surface height. A growing number of mirrors have been landing essentially "on the line", as we measure them. So you say to me, "how is that a problem?”

The problem comes in documentation. What kind of numbers do we allow to be printed when a mirror has its measurements "on the line"? Do we say 1/50 wave spherical? Do we allow 1/89 to print? Thankfully we no longer have that issue, as we no longer print numbers, and our certificates are now simply our performance guarantee and authentication, and a signature. I know it all sounds absurd, but it was a recurring problem. I kept coming up with docs that had values that exceeded 1/30 and 1/40 and 1/50 and beyond. So I would adjust the center of curvature constant to improve the RTA for example, so that the PV wavefront didn't appear so ridiculously accurate. You say you think that's funny? Well, perhaps it is. There are a lot of docs out there, if folks ever check them against other industry software that reduces Foucault data, that will have PV wavefront numbers that will read significantly better than the doc says, if they plug all the numbers in and reduce the data, and let the software find the position for best wavefront

value. And then there were extreme cases, where no matter where we put the COC constant that it just looked too good. I won't say at this point what we did, as it goes over the top and sounds too damn absurd. (I mean, what do you do when everything is on the gosh darn line, lie and make the mirrors worse???). Now having finished some number well past 1,000 mirrors, doing the same thing day-in and day-out, obviously over time we learn and develop techniques to do the work better and better. It is true for any trade. Anyone who specializes in one thing only, over time, they're going to get better and better at it.

We do one thing and one thing only - we just make paraboloids. As time has gone along our technique has continued to evolve. I've noticed that no matter how much time goes by and how many mirrors we've done; we continue to get better at what we do. The mirrors we make today in general are better overall than the average mirrors we have made in any point in time in the past, and it continues. This has gone on to the point where a majority of the mirrors now would seem ridiculous if we were to continue to print the numbers on docs. What I'm saying here is, it is a RELIEF to not have to print the numbers on the docs, because many of them are accurate to the point of being silly. As I mentioned in my last posting, we uploaded the M-L graphs for the last six mirrors we have just shipped, as an example. There are no numbers attached, just the knifedge plots in the Millies-Lacroix graphs. Those of you who have studied RTA on this group in the past will realize that slope error shows up the strongest in our former documentation, and these are the slope error graphs. The corresponding wavefront spherical aberration graphs will be to the point of absurd for accuracy if a number were attached to it. So what I'm saying here is this certification change has given us this newfound freedom that we didn't have before. And yes, it is going to sound terribly ridiculous, or absurd, or, well, whatever descriptor you can come up with. We now have the freedom to make our product as accurate as we damn well please and nobody can throw stones at the method of measurement or our documentation, because nobody knows how accurate they are! (...Well, I did say it might stir some controversy.)

What I didn't realize before is that with true mastery things begin to happen that no one else can really understand. Being a reputable commercial optician those years ago was not sufficient for me to understand what Bob Goff was trying to tell me, because he was so far ahead of where I was at that point. I thought his standards and tolerances were kind of absurd, myself. So I really can't expect that anyone reading this will in truth understand what I'm saying. So be it. But what I'm saying otherwise is, the work continues to improve, even without the printed numbers. The mirrors continue to generally become even smoother in the large-scale surface, which is a result of how we have learned to work the figure, over the years. And yes, there is now a freedom afforded to us that we can pursue any level of "perfection" that we desire, and without recrimination. I'm very pleased for the certificate change. I think it will be good in every respect, for everyone involved. CZ

New certification and end of an ERA

Kimball, Very articulate and well put. I was sad to see the era go, indeed. We are now more politically correct, as you have indicated. We are now more "watered-down", from a technical standpoint. The good news is, the product will remain the same, or better, as

time goes along. A note on this subject that I have alluded to before; those few folks who want to measure their mirrors by same method will always find an interested party here, willing to help. I will not withhold our (raw) measurements from such an individual for comparison purposes. As I've said before, we've always been about education as well. Thank you for posting your thoughts. Carl PS I have to admit I don't know what trigger chips are.

Carl Z, My thoughts on your announcement: We lose the technical and entertainment value of your specs, even if for no other reason than to both laud and scoff at them, for all the right reasons, while learning in the process; There are always a few of our monkey-like species who manage to combine a lack of intelligent perception with a dearth of principles to screw things up for the rest of us -- it is just part of the Human Condition. Without the discipline of moral principles, we are just a bunch of smart monkeys. By doing what you are you convert the earlier spec sheets into the astronomical equivalent of Trigger chips . . . there isn't no more where those came from. An age passes, only to give us a more politically correct, less disputatious, but more watered down future better suited to the less perceptive bozos among us. Long live Trigger chips, Kimball Corson

14.5" F-4.3 Starmaster

Daniel, Hey, congratulations and thank you for the report! I'm relived that someone is talking about their telescope and what they see in the eyepiece <big grin. My best wishes to you. Hey everyone, the planets are out! Richard, are you going to get a chance at one of them before they all disappear in the west? You don't have to answer that one publically :) Carl

Carl, We just took delivery on a brand new Hybrid. Just wanted to let you know how beautiful your primary is. We were splitting close double stars and getting wonderful views of Jupiter. At first there was some astigmatism, but it was coming from the secondary housing that was screwed on too tight and pinching the Protostar secondary. After we loosened the screws a bit, the secondary was able to breath. We verified this by spinning the primary during the star test since there was no change in the astigmatism. Now the star test looks gorgeous and the views are great. Thanks Daniel Mounsey

Thoughts on recent posts (VERY LONG and Rambling)

Thank you, Jeff. Tonight I fear I'm going to bump into my wife all the way on the other side of the bed with a head that is bigger than it already was. I truly appreciate what you have said. Yes, in light of all that, one might wonder why we're doing what we're doing. I hope my explanation was such that you understand it. There's one more thing that I haven't expressed plainly, and you seem to be one that can draw it out of me. Here it is-given everything you've said; that individual or company who is described as such has a moral obligation to serve the community in the best way possible. A part of what we're doing is to do our part to level the playing field, to contribute to making it fair for everybody. Yes, the guys that use interferometry and use it as a selling point made that

choice to put themselves where they are. At the same time, the guys using interferometry will not be able to compete equally by the numbers with the guy using the knifedge, because generally he won't have the same numbers. Although the educated can understand and interpret the differences, I would say the majority cannot, nor should they have to. If we can make things fairer for everybody and it doesn't create undo cost, then why not do it. I don't believe we *need* documentation to sell our mirrors. I'm not sure we ever did.

I'll tell a story that toots our horn, but I'm not telling it for the purpose of tooting our horn. When Rick took delivery of our first five 7" mirrors (our very first commercial mirrors) he was testing all five on the same night along with other 7" scopes with mirrors from other sources. His helper was working with him, and had the first look through one of ours. He said, "Rick...uh, you better come see this". So Rick took a look and said something like, "uh-oh, we have something here." Then they looked through another one, and exclaimed, hey, this one is the same. Then Rick told me he was thinking, "Nah, they can't all be like this". The rest is history. He gave me an observing report from Florida on one of those first five while making a delivery at the star party. He said it performed great and kept a good image at over 50x per inch but that now he had a problem. "Now other mirrors look like sh-t."

The point of the story is, from day one it was performance that promoted and sold our product. It wasn't numbers that made us who we are, and it wasn't the 'different' name, as one claimed some time back (Smith and Wesson are plain names, but you KNOW what that means). I'm going to step down from the documentation fray that's out there, because it’s a pretty big fray, and let every one else work it out how they need. That's the best I can do to promote fairness. I wish all the others my best. CZ

Thanks Carl for the reply. You know, I am HUGE proponent of the Internet... <snip ... And if you ever drop an 18 inch mirror and chip the edge. I'll be happy to give it a home in my lite box. Chip and all! LOL!!! Best wishes, Jeff

Bob, so you got one of the 7's, very good. There were about 40 of them total, maybe a couple more as time went along. There was no printed documentation for those mirrors, and for our in-house measuring we used the spreadsheets that we used for the early telescope makers who built scopes in our shop, long before we went commercial. Those 7" mirrors were figured for $75.00 a piece. That would have been okay back then, but the polished spheres coming from the glass supplier were so bad we would literally spend days polishing the astigmatism out. It was in truth an investment in reputation, and I'm so very thankful I was as hungry as one could be at that time to do anything that came my way for any price. Those 40 mirrors gave birth to a reputation. I'm still amazed at how quickly I was seeing my name all over the US, after such a short period of time. I'm looking forward to doing the 8's. I have yet to see a picture of the prototype, but from everything I'm hearing it might become something that makes a mark on the industry. Apparently it has every feature one could want in an OTA for both visual as well as photographic use, -rotating rings, sliding focuser to move the focal plane, and so on. And it’s a truss (all aluminum construction), so there are no tube currents. It is lightweight,

and is designed to mount equatorially for all the folks who have small refractors and want to have some aperture on their mount. This is rather speculative, but I see an OTA such as this possibly becoming a staple in the industry, something that every refractor owner with an expensive mount might want to have. And the price will be right too, less than a premium 4" refractor. Still some work to be done, the prototype is still getting fine-tuned. But I don't think the official announcement by Starmaster is far off. Oh, and the mirrors won't be half-bad either :) CZ

Carl, I can attest to the performance of one of those "potato chip" mirrors you were describing. You reportedly were given some blanks that were not of the highest quality and returned the figured product to Rick that stands as testaments to your early work. I know, because I owned mirror #5 in an Oak Classic and to date had the best lifetime view of Saturn at about 70x/inch with that scope. A couple of years ago, you were only giving RTA values for those early mirrors but even then, it really did not matter, because the views in the eyepiece were all that I was concerned about. I plan to get one of the new 8" f/5.6 open-tube Starmasters that you will be involved with and don't really care about numbers. Just give me the performance I have come to expect and you will continue to have a very satisfied customer. Thanks, Bob Schilling

Jeff, I don't blame you for choosing to observe. I don't get to meet most of our customers, but I'm certainly with you in spirit (there has to be more to this than just a job). I like to think that when you look through the mirror at the universe, at some point during ownership you might have a fleeting thought about the mirror maker. Perhaps in a sense at that point we're meeting. It’s a bit syrupy, to be sure, but I like to think that at some point we who make up ZOC are with every one of you. When you see the "good stuff", know that we wanted you to see that, and that the effort we made was for that purpose. And if we get the opportunity to all meet at the eyepiece itself, that will be fun as well.

Carl Oh well I've said enough (more than enough). I regret not meeting you a few years ago at RTMC. (I was observing and declined an invitation to kibitz with you and, I gather, Rick.) I always choose observing to BS'ing! .... Okay ... NOT! LOL! I just must have wanted to observe that night or perhaps someday at Shingletown, or OSP. Or even a star party in WA. Best wishes and hope to meet up with you somewhere under cool, clear, and dark skies, Jeff

Performance at the Eyepiece

Yes, that is correct. The term "side by side" is an important one, and must not be overlooked. Note that when Starmaster needs a critical evaluation, multiple scopes are tested. Rick's favorite scenario is when he gets six each 14.5's at one time. The conditions may limit what one can do overall, but when you have multiple mirrors that are supposed to be identical set up side by side, it becomes very easy in a star test, to see one that is not the same as the rest, because under the conditions any errors due to equilibration and such will be same on all. There is really no escape in a "side-by-side" to the trained observer. CZ

Barry, The extent of the fainter nebulosity, I should mention that the extent of and detail within the nebulosity (and the number of stars that appear embedded within M-27) are, influenced by transparency, as I am sure everyone knows, and seeing, which some folks tend to forget if they are not viewing the Moon or planets, so scope comparisons separated by time and space can be misleading. Clear skies, Alan

There is really no escape in a "side-by-side" to the trained observer. CZ

I would add, "provided that the scopes have the same thermal dynamics behavior". In other words if one has a cell of different design (closer etc.), a thicker mirror (or of another material), a different cooling fan arrangement, or even a with/without shroud (not to mention one might be over grass and another over pavement) the two identical mirrors will behave differently... wouldn't you agree?

Mauro, I agree with your points in themselves, yes, all factors must be in place. At the same time, performance is performance. "Side by side" will be in the same location, and have the same conditions locally, so those factors are handled. When we compare side by side we're comparing *systems*, as you have pointed out, and that is indeed the point. The complete systems side by side are the great equalizer. We don't say something such as, "Well, this is really a better mirror than what you're seeing because the glass is too thick, or the mirror cell is not up to par". It is up to the scope designer, optician, and all related to put together a system that performs. The final result of the equation is at the eyepiece. It determines the performance of the system. And side-by-side takes care of all other factors, and that is the point. If anyone wants to compare with our product, we ask him or her to set up side by side in real time, in real conditions. You better have your baffles in place and your optics collimated, because the bottom line is the bottom line.

On that note I recently had a conversation with Pete Smitka at Mag 1 concerning his 12.5" Portaball. We're using a new 1-3/8" thick primary with a wide bevel on the backside. With his relatively new sphere which has air ducts in the rear and his fan system, he reported the substrate making a 20° change to ambient from room temperature to outside air in as little as 35 minutes. It was within 2° and ready for high-power observing. CZ

Mote of Dust (OK - fleck of paint)

Jack, The mirrors you washed did not have a functional overcoat. I've stripped mirrors whose aluminum was gone in 45 seconds, using ferric chloride. But when I strip a Spectrum mirror for example, it takes no less than 3 hours to get all the aluminum off. There can be a lot of variation in overcoat quality. Coating is an art as well as a science as I see it. It is a trade unto itself, which is why we leave it to someone else. As long as someone else can do it well, I'm not going to get into it. We would rather spend our time doing what we do best. I have no issue with washing a well-coated mirror from time to time. Typically there is no consequence to the exercise other than a brighter and more pristine reflection.

Carl Hearing about this company and the flaws in the Hubble mirror reminded me of a time when I was in grad school helping build a gas laser. Two highly polished expensive end-mirrors were crucial parts of the laser. Seeing that the mirrors were dusty the professor said, "Rinse them." When I placed the mirrors under water, their reflective coatings just floated off like soap scum. End of experiment and a whole semester's work ruined! I still don't know why the reflective coating was so flimsy. Luckily the prof found it funny. I've heard ATM's extolled open frame tubes, for example during Mel's popular "scope walks" at OSP, where they say, "You can just roll it up to a hose and wash the mirror!" And indeed they are pushing the state of the art with beautiful new designs ... it's an exciting time for amateur telescope lovers. However, it's just me, but to this day something inside still cringes when I wash a good mirror or hear about others doing so. :) -Jack

Synthetic Optical Pitch

We have limited experience with one lot that is softer than we normally use. Initially it appears all is typical, with the exception that it doesn't smell so much and is clear- no more black stains. We didn't notice any need for technique change with figuring, except that this type was soft by our standards (which has its plusses for fast paraboloids.) Will be trying other hardness types in the near future. Surfaces appear initially to be same. If the pitch works adequately the anticipated upside will be that laps can be used over a longer period of time without discarding the pitch. ***Right now we change out Gugolz laps after 6 months, as they do harden up noticeably over that period of time.*** Not so important if you have two or three that you use, but it makes a difference if you have 40 or 50 that have pitch on them at all times. We do a lot of re-pouring of figuring laps to keep them supple and manageable. CZ

See: http://www.salemdist.com/Acculap.html any comments on how well this stuff works? Do you have to change your polishing techniques with this stuff compared to traditional pitch formulations? Does it provide smoother or rougher surfaces? Thanks in advance. Tom Krajci Tashkent, Uzbekistan

Checking for Astigmatism w/ Foucault

Robert, We gave a treatment on the subject elsewhere. RMS or PV results as numbers in themselves are not good indicators. In fact you could have the same values in two axes and have a mirror that is highly astigmatic. One axis could be overcorrected and the other one under corrected to the same value. The way we look at it is a graphical representation as outlined above. You can graph the wavefront profile as well as the M-L tolerance. If the correction from center to edge is different beyond error of measurement in any compared axes the mirror has primary astigmatism. CZ

Since we have talked about Foucault recently I wanted to ask about astigmatism. How do you determine the absence of astigmatism? When taking measurements against a mirror say 90 degree apart. What is it in the results that you would very no astigmatism is

present? Is it the agreeing of the RMS and PV result on both axis? Robert

16" F5 Plate Glass Figuring Observation

Dale, considering how many mirrors you've done to date, and the aperture and thickness of this mirror, I think you've done a good job. To go beyond that point takes many more mirrors, more practice, more mastery, and so on. There is a threshold point where I think you essentially are right now, where it takes a lot more mastery to get returns that begin to diminish. I'm not saying its not worth doing better, I'm saying it will cost you more in experience. The only way I know how to get that experience is with a teacher, or by doing many mirrors and learning first-hand. The "Dino" curve is indeed a common curve as you have noted. Good observation! I have seen it on other commercial mirrors; specifically those who do hand work with the tool on top, and possibly use only one lap. The turned down edge could be for many reasons, I don't necessarily subscribe to your theory. It could be hand pressure decentered on the lap. It could be poor stroke technique including too much overhang. Pitch that is too hard can turn an edge very quickly. There are too many variables to decide that one from here. In short, it is not uncommon to see a turned down outer zone from operators who do hand work "tool on top". The "sine wave" or "Dino curve" (with the TDE) can be created using a 50% diameter lap for most or all of the work. I don't know how to describe mechanically how it shapes, but it is a common curve when using one lap of that ratio, stroking across the mirror from edge to edge mainly through the middle, and with some offset. It is pretty much predictable. It has been a long time since I did hand work with a 50% diameter lap, but I do recall that one answer to this shape is the effective use of the "W" stroke, which in part is knowing when to go over the 70% zone.

Also combined with that is to know when and how to use more offset. Larger offset causes the lap to behave like a larger lap, and when positioned correctly during the correction process, can smooth out those two humps. But at this point with the mirror fully corrected, I don't know that it can be improved further without taking some major steps backward. Our machines do not perform the "W" stroke, so use five or six laps to do a 16" at F/5. We have a different lap for different radii on the mirror, and we blend the use of one lap and radius into another. We generally step the lap sizes by 1/2-inch increments. That is why we don't have classic sine waves on our figures. There are many variables to mirror making, as you already know. I'm not able to offer one simple answer to do anything more to the mirror. If I had to improve further on the mirror I would probably have to pour a full diameter lap to raise the edge, de-correct the mirror overall and smooth it, then go back to correcting it using different size laps. In other words, no simple answer to this one that I know of.

I think the mirror is a good job, and even more so considering where you're at right now, and that you used only one lap. CZ

I have uploaded a Foucault image of my 16" F5 plate glass mirror to the Files\eason 16 inch folder. This image was taken with the knife at .144 inches from ROC. I uploaded this image to get an evaluation of the surface roughness from members of the group. It

has a few scratches that show up as bumps and curved lines. The vertical parallel lines are from diffraction of dust on the CCD window. There are about two of those. I'm wondering how the rest of the surface looks to you. Second I have also uploaded the Sixtest results of my Foucault testing using my High Resolution Foucault computer testing. There are about 180 zones or one zone per pixel. But here is my question. Notice the curve of the error. I have seen this curve several times on other test reports. In particular on Obsidian's web site for instance here: http://www.obsidianoptics.com/specs/SN0321.htm and here: http://www.obsidianoptics.com/specs/SN0205.htm. I have had a hard time changing the shape of that curve. About all I have been able to do is reduce its amplitude. After seeing it show up on other mirrors I wonder if it is systematic. My figuring is done manual using an 8" lap. After having read Carl's post about humidity I have the following theory about the cause of this curve. I think that evaporation at the edge is causing cooling at the edge and shrinkage of the plate glass. I have measured the temp of the mirror after a 10 minute figuring session with a non-contact thermometer. It shows that the outer 1-inch is usually 1 degree F cooler than the rest of the mirror. Because the glass shrinks it gets less work at the edge. But the pitch also tries to fill the void. So on the return stroke the pitch is a little higher and carves the little valley one inch or more inside the edge. My basement shop conditions during this have been very cold in the winter with low humidity (40%-50%). Temps about 65 deg. What do you think? Is that a possible cause? I have been attacking this curve by trying to reduce the middle hump. By the way I have been calling this curve Dino because it matches the back of Dino the dinosaur. I have also been trying to keep my sessions short so that cooling is limited. Dale Eason

Dale Eason writes: I'm trying to determine how well my test system can measure TDE. At our shop we don't measure TDE. A classic TDE has slope that is so steep that it throws light outside the airy disk by multiple diameters and should not be used in the aperture. Because you can measure pixel by pixel I would guess that you could measure it, up to the point where a wide diffraction ring exists. Regarding definitions, there is a place where an overcorrected outer zone becomes a turned down edge. The definition of that place might be equivalent to when a creek becomes a river. They seem to merge somewhere that is not clearly defined. According to my experiments the diffraction ring overlaps the real edge of the mirror by about 2 pixels that is about 1/16 of an inch. So I normally tell my program that my mirror is 1/16 smaller in radius than actual.

That sounds about right. You mentioned the TDE. Was that from inspecting the image? No. The knifedge null is not at the edge of the mirror; it is closer to the 50% zone. There is no inspecting the edge at that knifedge position. I'm going by your graph. I'm calling that sharp turn by general description a turned down edge. More technically correct, since you measured it, it might rather be called an overcorrected outer zone. The test results might be a little suspect. Since many times I forget to adjust it so that it doesn't measure diffraction ring but only just to the edge of it. When I include the diffraction ring I get a very steep turned edge that I don't think is real. I would not attempt to measure a wide diffraction ring (classic TDE) because in practicality it is moot. I would say discard that area, because it is unusable. However I think there might be one since the ring is not real bright in the Foucault image I posted. The image does not apply for examining the edge.

See above. You can't see the entire mirror at one knifedge position. A paraboloid is an aspheric conic that is equivalent to a succession of spheres of ever increasing radii of curvature as you go from the center to the edge. The knifedge null has to be at the radius of the sphere you want to inspect, in order to see what is going on there. Other places at other radii of curvature will be either dark or light, but not gray.

Inspecting the Edge

If you want to inspect the edge, you put the knifedge in position to null the edge of the mirror. Go to the bench images folder in the photos section and see the last three images, "null center", "null zone 4" and "edge null". See the difference in where the crest of the "doughnut" is in each image, which is the position of null. The mask in each case demonstrates this position. See that the gray area, or null, is where the hue is the same on opposing sides of a particular zone. To inspect the edge condition, the null needs to be near the edge of the mirror, as in the last image. You can see the diffraction ring on each side right and left, and that it is balanced. I'm not sure when to look for the bright ring. When the knife nulls the center zones there is none but it is very bright when nulling the edge zones. The posted image is a null of about the 70% zone. I think you figured it out. I think the average of my measurements shows about the last 1/4-inch or less is turned down about 20 to 40 nm. Is that confirmable from the uploaded image? No.

Knifedge measures slope very well, but is not so good at showing slight overcorrection at a glance. A Ronchigram is better for that, as it will show the entire mirror, because it has many knifedge where the light can pass through them. The different radii of curvature from the different points on the mirror will show up as curved lines. An unusual amount of over correction can be evaluated (but not quantified) by the trained eye. Another question. I have heard you and others talk about smooth figure or a figure without steep slopes. I have not seen it quantified. How does my surface qualify in this regard? I assume that it probably is a little too steep where it bottoms out and comes back up. It has been quantified, at least by my definition. We have talked on this forum about RTA and its significance, and the ability of the knifedge to measure slope error, which is its strong point. (Amazing how Steve anticipated this one...). I have to say I don't think so well in nanometers, I think in micro inches. So your graphs require me to do mental gymnastics to evaluate. Even still, when it comes to smoothness of figure, in my mind I leave the surface and migrate out to the focal plane where I compare rays traced from the surface to the airy disk.

I would suggest going back and reading the very thorough writings on RTA, along with the supporting graphs in the photos and files sections. Keeping the slope within the Airy disk mandates a smooth enough surface, and RTA is the most difficult criteria to meet in the making of the mirror. That fact that we maintain and use that tolerance is what put us on the map and keeps us there. By the way I am planning on trying to get it better before calling it finished. I do have a full sized lap. I'm not opposed to going back to the full size lap if it helps improve it in the end. After all I have only been working on it since last July :) At one point it was 2 waves overcorrected. You remind me of the tenacity I had when I was a "greenhorn". CZ

Jack Semura wrote some time back: ...Forgive me Carl, but I have this fanciful mental picture of Carl sort of inside a renaissance painting studying one of his mirrors with critical admiration... You're forgiven, Jack. This one's for you. CZ

From the Starmaster user's group:
http://groups.yahoo.com/group/starmaster_scopes/message/13103 Gordon: Nice to hear from you. Buster and I remember buying the little Meade refractor from you, despite the color in it, I used it to hunt down asteroids from my front yard, believe it or not. Larry has a 36" Obsession, one of 4 made. There were 3 36 inchers at TSP this last week. 2 Obsessions and the "Yard Scope". I got to look through 3 Starmaster Zambuto equipped scopes, 12.5 thru 16 inchers. They were looking at Seyferts Sextet at the time. With very high contrast they were able to spot all 6 galaxies at high power. Larry remarked that he looked at M51 through these scopes. He even remarked to me that he asked the owners what kind of mirrors they had. He said he could see all the detail in the 16 inch that he could see in his 36" just dimmer. Of course, it helps knowing what to look for. I was looking for a plume coming off an Arp galaxy, and could not pull it out with my 20" but Jim Chandler's 25" could. Aperture won out in this case. Barbara CZ

12.5" f/6

Shannon, We supply mirrors in finished telescopes, two focal ratios for 12.5": Currently Starmaster supplies F/4.5 and Starsplitter and Mag 1 Instruments 12.5's are at F/5. For F/6, and especially if you're looking for a mirror only, as you have indicated I would recommend an Astrola mirror by Larry Hardin. Carl

Mr. Zambuto: What focal ratio(s) do you supply in the 12.5" size? For Starsplitter, would that only be an f / 4.5? Would Mr. Hardin be a great alternative source for a 12.5" f / 6? - Thanks Shannon Mann

ATM list

The ATM list had a site address change some time ago. I have not re-subscribed so I don't have the info in front of me. I imagine a simple search will turn it up again, or there would certainly be a link from Bartel's site. Although this list is not particularly about ATMing, we have answered questions about Newtonian mirror making for those who have asked, to date. Perhaps the reason is because it educates readers about what is required to go into the fabrication of a good mirror. It raises consciousness about primary mirrors, and helps with perspective. There may also be other professionals who might glean information from here as well, and if it raises quality and standards for the whole industry, then it is a good thing. Whether it "demystifies" some of the process for others is unknown to myself. Personally I don't mind a few questions about mirror making and its relationship to the telescope. Feedback as we go along from others (including moderators) is welcome to determine whether amateur mirror making is an appropriate subject for this forum. CZ

Hi, I´ve been to this group for a couple of months by now, always amazed with the reports and experiences of ZOC mirrors owners. Unfortunately CZ doesn´t sells mirrors, so, I have to keep trying to make THE good one myself. I´d like to post some subjects about wet polishing, machines etc., but I think these subjects are more ATM-list stuff. I have tried several times to contact ATM list via list owner and www.atmlist.net, but I got no response from them. I was a subscriber of ATM list since 96, but I had to leave it for sometime and now I can´t return back :(. Two questions - is this list for ATM related subjects also? Someone knows what´s going on with the ATM list subscription? Regards, Ricardo Dunna

I left out something important regarding reasons for myself answering questions on ATMing, and it is this: I don't mind helping an amateur mirror-maker, as I'm not really that far removed. I was an ATM once myself, as are the majority of the mirror makers in the amateur industry whose names we know. There was a time when I had a question that I was struggling with. It was something that I wanted that no amateur was able (or perhaps willing is a better description) to help me with, as each reply said I should stick with the status quo. I was unwilling to do that. It had to do with our then future documentation. The programs out there were not suited for measuring one mirror after another, plus their graphs have limitations, and so on. Then one day later on, while reading the ATM digest John Hall responded to my query. He didn't have precisely what I was after, but he offered what he had, and that was his personally developed, Texereau-based, fully functional spreadsheet by which he does all his calculations. He gave it to me. You see, I have to confess I never got through Texereau, my math is that bad. So I was able to plug in, or should I say, "copy and paste" formulas that would produce wavefront numbers and RTA data in a spreadsheet. I never did learn how to build a wavefront mathematically so I left that to the math people. Later on, a student in my telescope making class I used to teach who was a programmer took pity on me. Knowing what I was after, he took the public domain basic program that I really wanted to get the formulas out of, and decoded it for me by plugging it into an Excel file. The formulas I needed were shrouded in subroutines that I couldn't get my head around. As soon as he got one Excel file that matched the result of the basic reduction program, I finally (after probably two years) had the formulas I wanted in my possession. And as I look at it now, building the wavefront is not that simple for the non-mathematician. My query would still be in the ATM archives, I suppose. I think I used the term "mule" at one point. Anyway, I'm willing to be of some help if I can be. CZ

Although this list is not particularly about ATMing, we have answered questions about Newtonian mirror making for those who have asked, to date. Perhaps the reason is because it educates readers about what is required to go into the fabrication of a good mirror. It raises consciousness about primary mirrors, and helps with perspective. There may also be other professionals who might glean information from here as well, and if it raises quality and standards for the whole industry, then it is a good thing. Whether it "demystifies" some of the process for others is unknown to myself. Personally I don't mind a few questions about mirror making and its relationship to the telescope. Feedback as we go along from others (including moderators) is welcome to determine whether

amateur mirror making is an appropriate subject for this forum.

Sixtests and Millies-Lacroix (was: ATM list?)

Nils, and group: Jim Burrows is indeed one of those mathematicians. I believe he has a doctorate in mathematics. Jim has visited this shop on a couple of occasions; we have worked together on a project or two. By "working together", I mean my job was to supply an optic with a smooth surface so he could test his math. Jim can write algorithms that will make a PC sweat for a good long time. I'm amazed when I watch his Hartmann program work. Jim now knows well that when we correspond he is not allowed to talk in mathematics, as the language is mostly foreign to me. He has to talk to me in concepts, only, which he now does well, so we get along just fine :) Sixtests is a beautiful program. It follows the wave nature of light that is the reality of how light operates. When I began as a mirror maker such a program did not exist. I read the article in Telescope Making Magazine #6 (TM mag disappeared a long time ago, for those newer kids on the block. The "old-timers" pride themselves in having complete collections of the magazine). The article was "Stalking the Wild Paraboloid" and was a revisit of the Millies-Lacroix Method of determining a mirror's state of completion. Nils mentioned a "dubious" concept with regard to the method. As far as theory of light goes, that is correct. However in function it works beautifully.

The beauty of M-L determination is its extreme simplicity. It was simple enough that this mirror maker could run the simple formulas and graph the plots. Later on, I transferred it over to computer, and it became a part of our spreadsheet and documentation. I'll revisit briefly the fact that the two methodologies of determining mirror completion have been argued against each other for quite some time. Mathematicians like the wave-based software because it is correct in theory, that is, how light actually works. Many mirror makers like the ray-trace (M-L method) because of its elegance and simplicity. We know that light doesn't travel in rays, but functionally the method is extremely adept. One argument on the wave side is that the M-L tolerance makes a mirror better in cases than it needs to be. Well, that's a matter of preference. In large part the result of M-L tolerance is Zambuto mirrors. I'll let history be the judge. For those students who are studying our work, I prefer to keep things as simple as possible, because when it comes to math that is what I can get my head around. One thing I do know for sure, when you get the plots of a smooth mirror inside of that tolerance, it doesn't matter what the wave rating is. The mirror will go to 50x per inch, because the slopes are very well controlled. If any mirror makers out there wish to learn the simple formula for Millies-Lacroix tolerance and how to put it together, I suppose we could go over it. The original article was in Sky and Telescope magazine in 1976 if I recall. Of course, there is plenty of software out there now that does it for you, so it isn't a necessity, but I liked drawing the first graphs by hand many years ago, because I understood what I was doing myself, and why I was doing it. CZ

Carl and others, you see, I have to confess I never got through Texereau, my math is that bad. I was able to plug in, or should I say, "copy and paste" formulas that would produce wavefront numbers and RTA data in a spreadsheet. I never did learn how to build a

wavefront mathematically so I left that to the math people. Given the limitations he had, I guess Texereau did a very good job - the number-crunching capacity we all have available before our very eyes is way beyond his least realistic dreams no doubt ;-) His method of "geometric integration" (as described in How to Make a Telescope) is quite simplified, but even so, a good bit more complex than what most of us would put up with. Later, Millies-Lacroix suggested an even simpler graphical method to evaluate the data, based on a dubious (to say the least) concept but still kind of useful - and some later attempts to computerize the process have been based on these methods.

However, since the subject has been brought up, I'd like to take the opportunity to mention that Jim Burrows (who is indeed one of the "math people" by any standard!) took a fresh approach by deriving the differential equations from scratch and applying well established numerical methods to solve them in the best possible way - the result is SIXTESTS. This program is built on the exact differential equations for Foucault, Gaviola and "Poor Man's Caustic" tests for either fixed or moving source (six combinations, hence the name), employing "state-of-the-art" numerical methods to derive the profile estimates. Incidentally, the solution for the now not very common PMC is the first (AFAIK) to be fundamentally correct - not to say even remotely useful. His work has been expanded by others like Dave Rowe and James Lerch with FigureXP offering some very nice "frills" in addition to the basic features of Sixtests, and there is also a "front end" written to ease the data input to Sixtests, but the main point is that now (alas, only so far Windows or DOS users, I believe) we have the (freeware!) means to get the most out of our measurements. Obviously, though, these new generation programs do not address or solve the inherent physical problems and limitations of Foucault and related tests - nor of course the practical problems of improving the mirror figure, once you know it. Nils Olof

Nils writes, Thanks for the tip - I guess those messages say just about all there is to say about the M-L. The criterion is very indirect in that it is based on slope rather than wavefront error. It is only indirect if you're trying to achieve something other than defining the slopes on the surface. Keep in mind that the test measures slopes, first. The wavefront is built from those slopes. Please recall that Mr. Suiter in his posting on the thread on this subject (pointed to recently by Michael) stated that slope and height errors are two sides of the same coin. The point is both contain valuable information for the mirror maker. The fact that Sixtests does not use slope values as any final arbiter does not necessarily mean that slopes have no value. In fact it is possible in theory to have a mirror that would fail the Rayleigh 1/4 wave criterion and still meet the M-L, but not very likely in practice -and anyway, a curve that is too weird won't give reliable readings anyway. The only way I know how to have any chance of constructing a wavefront that would fail Rayleigh and meet ML is with a very smooth mirror, such as smoothly under or overcorrected. M-L is the more difficult criteria to achieve, so that is why. You use the example of a curve that is "too weird". -Weird curves don't meet the M-L criteria because of their slopes. The fact is I hold that just the opposite is the case. I can show you a 1/10-wavefront mirror that has slopes so bad it would not pass the Millies-Lacroix criteria, and so in fact would not pass our standard.

Carl says: The beauty of M-L determination is its extreme simplicity. It was simple enough that this mirror maker could run the simple formulas and graph the plots. Later on, I transferred it over to computer, and it became a part of our spreadsheet and documentation. On the other hand, if you've got a computer (something I am sure neither Texereau nor Millies-Lacroix had!), doing it properly <G is just as simple and, to my sense, even more beautiful! It has not been established to my satisfaction as a professional mirror maker what is "proper" and what is not. That thread mentioned above points out the not-too-obvious fact that the M-L profile is NOT the mirror profile - on the other hand, Sixtests and Figure do show the profile estimated - it may or may not <G help your figuring if you know it... The M-L criterion is not a figuring tool, any more than an interferogram is used for figuring a mirror during most of the process. It is a final "go, no-go" criterion for passing a mirror, as I hope to write about in a subsequent article. Then again, a very good mirror will get very good ratings by any reasonable test or any reasonable criteria - but if you want to stop at any finite point in time and call the figure satisfactory, you will do so by applying some criterion. I am happy to see that P-V is gradually being phased out of meaningful discussions, being replaced by RMS error or Strehl ratio (those are closely related, at least for "good" wavefront). This means that you need some data reduction method (and by practical necessity this means software) that can estimate the RMS error Using RMS error as a final arbiter *with the Foucault test* has problems. If that is indeed the case, then a reduction program which uses Strehl ratio solely as a final criterion for stopping at some finite point will not be in the best interest of the serious mirror maker. However, it is no trivial matter to decide what method is "best" here - I took the sentence out of context from your post, but as it stands here, I agree.

Another point perhaps worth bringing up is that Foucault (and related methods) testing is a matter of wave optics, not geometric optics, even if the data reduction methods pretend the latter. Nils Olof understood that. What I'm going to say next is for the benefit of amateur mirror makers who are studying this forum as serious students. I'm not going to let a blanket statement such as "doing it properly" go unchallenged. What I see being claimed here I see as largely theory. When I speak of methodology, I'm speaking from where the rubber meets the road. I want to see someone try to make the claim that the Millies-Lacroix (and before that the Danjon and Couder criteria) tolerance doesn't work for the mirror maker. I want to see anybody try to flat out tell me that such a criteria will result in a mirror maker fabricating a poor optic, or one that does not meet a known standard. I want to see someone put their reputation on the line in public and claim the M-L tolerance will not produce a consistent star test, or be a standard for controlling astigmatism that is visible in the star test. I want to see such a person deny the fact that a mirror made to such a standard will not produce an optic that shows no visible error under actual use in focus. End of that rant, begin rant next:

I do understand we're talking about criteria for stopping at a particular point. That being the case, the way I see it, the path that is claimed to be "proper" is in fact misleading and can get the mirror maker into serious trouble if they are a serious student. I'm going to go on record saying precisely the opposite. I'm going to say that using the final criteria of Strehl ratio or RMS wavefront combined with the knifedge test (Sixtests for one

example) will be misleading to the mirror maker, very possibly giving them wrong information about their final product. I'm going to go on record saying that the Foucault test is not able to reliably predict Strehl ratio no matter what reduction software is used, *when the slopes exceed the M-L envelope*.

I'm going on record as stating that when a mirror maker does not control his slopes and uses the knifedge test, they cannot rely on the Strehl ratio information spit out by the data reduction software. Based on my professional experience with our documentation and our mirrors being tested via phase-shift interferometry, such is the case. Let's see if that gets a discussion going. Students- if you care to learn about this, get online and start asking questions! CZ

Nate, I "second" what Steve says, it depends on what your interest is. Tell us a bit about what you're specifically interested in at this time (always subject to change, of course) and we can hopefully direct you. And guys (Nils, Steve, et al) I'm not absent from the forum, I just have a lot going on and can only spend a short amount of time daily for correspondence. My postings often require a day or two of thinking. These discussions are very good, as they cause me to think through why we do what we do. I have a lot of responding to do on the current subject, as I think it is important, and non-trivial. I'll be getting around to participating, as I'm able. CZ PS Preston came by with his Dad for a shop visit today. It was very good; we all had a great time.

As I see it Steve, a significant problem with this entire discussion is the difference between theory and practice. You can run computer tests on mathematical concepts and indeed find a correlation between RTA and RMS. But my assertion comes from somewhere else. It comes from the failure of an aspect of the test itself. The problem as I see it does not lie with Sixtests, or the math, or the computer, etc. It lies with the Foucault test and the nature of it. The breakdown of the whole thing comes from the nature of Pyrex, of mirror figuring, and of the application and practice of the test itself. In actual practice the Foucault test has limitations whereby it is not a good predictor of Strehl ratio, with the exception of very close to an essentially perfect mirror. In my experience that is the only place where the Foucault test matches the interferometer. And if we disregard slopes as a tool *with the Foucault test* we will not get there. There is too much space between the points taken in a standard measurement to not account for it. There are large areas that have a slope that in my experience, as well as Danjon and Couder, et al, need to be accounted for. This is a good subject that is worth spending some time. I'm pleased you're running some tests on the computer; I think they will shed some light on the math end of things. I plan to stay with this subject for as long as it takes. Time is short at present, and I'm also away for the weekend, but I will get to each posting as applicable, when I can. Thanks for your patience. Nils, I'll be getting back to you, next :) CZ

Carl, I'm not a mirror maker, but the more I work with test data, the more I believe your assertion. I'm sure this has been done before, but I'm tempted to simulate a bunch of random mirror profiles, and evaluate them using RTA and RMS/Strehl, and see how and when the results differ. I'm not sure, yet, how to present the results, but I would like to determine if RTA is a good predictor of RMS error, and vice versa. If your assertion is

true, then there should be some difficulty in doing this, especially as RTA and RMS error get worse. I'm wondering if RTA is a sufficient single quality number for this test (i.e., a number which tells how closely the optic fits the M-L tolerance), or whether I also need some sort of direct M-L evaluation? Do you have an opinion on this? -- Steve Koehler steve_koehler@s...

References

Nate, It depends a bit on what you want to know. I have the following suggestions for a start: Suiter - Star Testing Astronomical Telescopes [for understanding the Star test and optical testing] Rutten and van Venrooij - Telescope Optics [for understanding optics And telescope design] I have found both these books very useful. -- Steve Koehler steve_koehler@s... -----Original Message----- From: Nate Andrews [mailto:Stratomech@c...] Sent: Wednesday, June 16, 2004 12:32 PM To: zambutomirrorgroup@yahoogroups.com Subject: [zambutomirrorgroup] Info Hi all, I find all of the conversations here and on the ATM list fascinating but I unfortunately comprehend very little. I would like to be one of the "students" but obviously there are some prerequisites. What books or other medium do you suggest for someone who knows little or nothing? Thanks, Nate Yahoo! Groups Links
Re: Info

Mr. Suiter's books are not primarily about physically making mirrors, nor are some others that have been suggested. Regrettably, there seems to be an absence of *good* books primarily directed toward mirror making. Texereau has been the default standard for many years. It is an old book and can be difficult to get through for some, but it is worth owning. All mirror makers most probably have Texereau in their library. Berry's book was mentioned, and it is good. It has an optics section that is reasonably detailed for doing a 6" mirror. It also has plans for five telescopes.

There is another one more recent that I've been interested in but have not purchased it yet called A Manual For Amateur Telescope Making.
http://www.willbell.com/tm/atmmanual/index.htm here is some text on the site about it: "This book is arranged into four parts. The first is devoted to the basics of optical glass working: grinding, polishing, testing and correcting (figuring). The remaining three parts deal with the specific steps needed to build each of the three telescopes described above. The text is augmented with more than 225 pictures and drawings. A noteworthy departure from other books is the detailed instructions the authors provide for corrective measures to cure optical difficulties encountered during figuring. It also deals more thoroughly than previous books with figuring the kind of mirrors used today with fast Newtonians or Cassegrain primaries. The authors discuss tests less cumbersome than the Foucault test in figuring these very fast instruments, namely the wire and caustic tests."

Other books in existence are Standard handbook for Telescope Making by Neale Howard, which I have in my library but have not used it extensively. It does have about 100 pages on mirror making. Also there is an older one by Thompson whose title I don't

recall at present. I think it’s a step by step for a 6" of older vintage. Most of what ATM's pick up is "here and there" from the ATM list, from teachers both good and bad <grin, from reading books, and from getting in there and just doing it. If the mirror is a "dog" and you're not afraid of ruining the figure, I would suggest just getting in there and doing it. No book is going to teach what you are going to actually experience once you get started. If you think that is the case, just ask Bob Mazzullo :) Cheers, CZ

I am currently involved in a telescope-building project for my club using a mirror donated to the club. I am mostly interested in testing and judging finished mirrors. Before this scope is finished the mirror will need to be refigured (it has been judged to be about 1/2 wave, and I don’t know 1/2 wave of what). There are others involved that are experienced but I would like to be able to understand and contribute more to the optics part of the project. I had Mr. Suiter’s' book in mind but having not read it I do not know if it covers any of the subjects you are discussing now, the terms you are using, and at a layman's level to help me understand all of this. From what I understand all of this will become very important to know before spending allot of effort polishing glass! Thanks, Nate

Choosing a Criteria RMS- or RTA

To the readership- everything I'm writing in this rather long article I write for the benefit of the ATM who is looking for guidance in making a mirror. Nils happens to be the person who is discussing a subject I'm addressing today, so I apologize to Nils, and hope he is gracious enough to allow me to use him for a sounding board initially. I've noticed he is willing to go toe-to-toe and argue in public with Dick Suiter, so I don't think my arguing with him should be an issue, as I admit I don't hold a candle to the stature of Mr. Suiter. Nils writes: it seems you are reacting very seriously to what I said! That is correct, I take this very seriously. Not only does it affect what I do for a living, it also affects every reader/ATM who is looking (lurking) here for guidance. This forum happens to have my name attached to it, so there is an inherent responsibility involved. This is not just a "place to play" for myself. I may be right sometimes, I may be wrong sometimes, but I take it all seriously, even when having fun. In other words, I may at times be informal, but I'm not casual ("Casualness breeds casualties"). Still, perhaps you can permit me a few more clarifying points - no need to agree or disagree for that matter....

But my main point is that the final criterion for optical quality is the phase coherence at the Gaussian focus - this is (to a good approximation for wavefront with small deviations at least) a function of mean square error from best fit (paraboloid curve in the case of Newtonians). Slope doesn't come into this - though it will to some extent affect how and where the light is diffracted. So I agree that slopes are (usually) valuable, not to say necessary, for estimating the optical figure. What I disagree with is that they would have any inherent, or direct, usefulness as a quality criterion. I think the reason was well clarified in that thread a year ago. As far as theory goes, I will assume you're absolutely correct. I cannot argue your point, as it is beyond my scope of mathematical expertise. However I will point out that is how it all goes mathematically, and more specifically, as done on a computer. I'm going to say something again, but in a different manner.

There is a difference between saying what is ideal (phase coherence at Gaussian focus), and getting there. Fellas with very sharp intellects, fast computers and lots of software can do a lot of wonderful simulations on the screen. But the computer does not manufacture (read: fabricate) the actual results at the eyepiece. For any who have not noticed by now, we here at ZOC are in the habit of using empirical results. I'm going to now engage more fully my main point in all of this discussion. It follows in part as an answer to one of your statements: Another point perhaps worth bringing up is that Foucault (and related methods) testing is a matter of wave optics, not geometric optics, even if the data reduction methods pretend the latter. Thanks Nils, for participating. What I'm about to go into is now directed to the readership/ students.

The way I see it the Foucault test itself is purely geometric in every major aspect. We are measuring a physical surface with triangles. That is geometry (trigonometry). We place a measured mask over a known diameter. We place a light source at a measured distance and a knifedge at a measured distance and move it with a micrometer. It matters not what color visible light we use, so wavelengths don't enter into it. We can use red light, we can use green light, and we can use white light. We can even use blue light! We measure distances which tell us of slope angles whereby we construct a real surface profile, which is also geometry. We are measuring and establishing the shape of a real surface. It is all geometry. And it’s fairly simple in concept. The mirror maker need not have anything to do with wave theory or wave optics to make a superb mirror (anyone ever hear of Zambuto mirrors?). We know the shape we're looking for. It is a conic section called a paraboloid. We know that the knifedge shift for a paraboloid is a simple formula, stated as r^2/R. -That is, the radius of the zone squared, divided by the radius of curvature of the mirror. Very simple and it's all geometry.

Wave optics enters in when we decide we want to see what the airy disk and diffraction pattern actually looks like, in theory, as well as calculate a Strehl ratio. If you don't care about what the airy disk and Fresnel rings look like, then you don't have to use wave mathematics in your calculations. We are working to construct a known surface shape. We know how to do that, and we can employ geometry to accomplish it. Now, the problem arises where we ask ourselves, being as there are no perfect paraboloids, "what is a viable tolerance, and how do we determine that tolerance"? This is where the arguments begin. Danjon and Couder stated a criteria a long time ago, one half of which (it is two parts) some present day mathematicians and computer experts want to go away.

Some say that relative transverse aberration is now obsolete in the face of wave optics data reduction, and should be done away with. I believe that Danjon and Couder were using the geometry of the Foucault test when they stated the criteria. Texereau certainly did. So do we. Here is the problem as I see it, in an example. I have seen a mirror whose relative transverse aberration comfortably exceeded the Millies-Lacroix tolerance, and which Sixtests reduced the data and claimed had a Strehl ratio of .96. I'm sorry, folks I don't believe that it can happen. I think that mirror is a whole lot worse than .96 Strehl. Suiter said on this forum about a year ago: "A pure correction error that directs a ray from one side of the Airy disk to the other at half the radius of the optic (in other words, the

worst 3rd order spherical aberration that is completely within the Airy disk) ... results in a Strehl ratio of about 0.92." I've said recently that the problem lies in the application of wave optics to Foucault data to determine Strehl ratio.

The proponents of that data reduction software apparently want to use the Strehl ratio criteria as applied from the Foucault test to determine a go, no-go situation. I don't think that a criterion alone is reliable for the serious mirror-maker. The reason as I stated before, is because of the nature of the test. Now, if on the other hand we have an interferometer plotting a few hundred or a few thousand points on the mirror, then I say lets employ wave optics, because every applicable place on the mirror surface is known but not so with the knifedge. For the amateur who measures six to nine points on a mirror, there is far too much space between them. There are wide spaces with slope angles between each measured zone. Because of this, I believe it imperative to deal with these spaces different, which is to trace a ray from that slope surface to focus, where it winds up. Let's take a simple (and admittedly gross) example-

When you use a signal mirror and want to change direction you tilt the mirror so the light goes to the place you want it to go. You don't think about wave optics, you simple direct the tilt, knowing the angle of incidence equals the angle of reflection. On the surface of the parabola, there are wide spaces between the centers of each zone, each of which has some degree of slope or tilt to it. When that slope angles one direction or another, I assure you, it is going to affect where the light winds up. (Yes, I fully understand that the Fresnel pattern is acquired through wave optics, from a combination of all zones combined). However, nevertheless, the bottom line is, in my opinion, the Foucault test cannot get you an accurate Strehl ratio rating when the slopes are outside the M-L envelope. Steve Kohler did some good work on RMS and RTA. From what I could tell at a glance they had constant ratios, as the graphs all moved in straight lines. I think that is probably how it is mathematically. But when it comes to application of the test, there is a failure to some degree at determining both, and that includes RTA, for the following reason.

Any localized error on the surface is averaged between the two matching zones on opposing sides (this is why smooth surfaces are critical to good mirror making). So the depression may wind up only having half the value, and then it is decentralized, and turned into a zone that goes all the way around the mirror. That is an inescapable artifact of the nature of the test. That happens for both factors, those being RMS and RTA. But that is the only problem with RTA, whereas RMS has an additional problems, and that is a lack of data points. So what to do?

Well, I'm sorry to say it, but to make a really good mirror; you have to make a really good mirror. In my opinion paying attention to Strehl ratio as an only criteria can and well may provide mediocre results. It might look good on paper, and when the number is nice and high the ATM feels real good. But then when they get it tested on an interferometer and the Strehl ratio is significantly different they can say that professionals don't know what the hell they're doing, and write them off. So on it goes, the gap between amateurs and pros continues. In case no one noticed, what we're doing continually is

setting standards for excellence, not mediocrity. We hold onto "obsolete methodology" because it works.

What I meant when I said to Nils that no one has proven to my satisfaction to date what is proper and what is not, is that I haven't seen anyone yet make a mirror using wave optics test reduction and its corresponding diffraction limit criteria that equals or exceeds our product on any consistent basis. We happen to know from star testing optics that were measured by our test and methods, that when the slope angles as determined by RTA exceed the tolerance we have spoken about so many times that you are going to see it in the star test. This tolerance is so effective that we use it to determine astigmatism as well. We know that when we control the SLOPES to that tolerance that no one will see astigmatism in the star test at any power.

And we also know that when they exceed that tolerance, it will be detected. I'm still waiting to hear anyone claim that this tolerance does not do the job. Here is where I come from- early in my mirror making as a hobbyist I read the following lines from TM Magazine #6. And if you save anything to a special file on mirror making, please save what you're about to read. I cannot stress enough the value of the following, to the serious mirror making student: "Although the Foucault test is notoriously hard to interpret, alternately too sensitive for insignificant defects such as central holes and hills and not sensitive enough for disastrous flaws such as turned edge and astigmatism, the mirror maker who follows the graphical method detailed here can evaluate his optics with certainty and rest assured that he knows whether or not his mirror will perform to his expectations. A single calculation will suffice for the entire figuring process. The key to this method (first presented in the February 1976 issue of Sky and Telescope by Adrien Millies-Lacroix) is a simple calculation of the exact tolerances allowable on a glass surface. A graphical plot of these tolerances shows how far you may let your curve deviate before such errors will degrade the final image."

Did you get that? "...How far you may let your curve deviate before such errors will degrade the final image." Some have said its "obsolete", but I want to see anyone say, "It doesn't work". So, what have we accomplished with that information? I made my first 8" mirror that let me see the spokes on Saturn for the first time, not only for myself but for many others as well. That tolerance also allowed every telescope maker from our classes we once taught who entered into the optical judging at Table Mountain Star Party to come home with an award. The first year they had to give away four awards, because they didn't know what else to do! They were all too similar and beat everything else that entered. And of course, that tolerance has also built our reputation, and this business. So, here's what I propose.

I'm not personally interested in criteria that shoot for "diffraction limited" via a Strehl ratio of .8 or better. I call that mediocre. If someone is studying what we do, they should prepare themselves to strive for the finest they can do. It is an achievable goal. I propose that the criterion the serious student uses is the Millies-Lacroix tolerance as a minimum. What it does is keep the large scale measured surface very smooth. Using wavefront alone, the slopes can be quite steep and have "kinks" in them, but still fall within a

wavefront tolerance. The ML tolerance using slopes will cause that necessarily to smooth out. As Mr. Suiter pointed out, slope and height are two sides of the same coin. I'm of the strong opinion that the amateur mirror maker who uses a knifedge to do their measuring and final criteria should address them both. The more difficult criteria are the slopes, and in fact one will take care of the other. Once everything is in the envelope, the wavefront rating doesn't really matter as much. Doing what we propose is not a crime other than using a tried and true method that those who put their faith in technology call obsolete.

When I was in Bob Goff's lab I looked at everything I could lay my eyes on. One thing I saw was a hand-drawn graph for a mirror project. What was on that graph was an M-L envelope. Bob had all the latest stuff, including fast computers, an interferometer, and much finer software than the average professional shop uses, which is ***Intelliwave***, a program more on the order of about $5,000.00. But when it came to a tolerance for a mirror, he used the simple envelope we use in this shop as well. The way I see it, if somebody wants to know where the rubber meets the road, then one should ask the person whose living depends on their results how they do it. So as I see it, the argument boils down to choosing criteria for a tolerance. You can choose the latest software and use Strehl ratio, or you can choose to use an older (and mathematically simpler) method, and control your slopes. The choice is of course, up to the individual. CZ

I'm not in a position to disagree with either Bratislav or Scott on this one. At the same time I wish to point out that I understand these statements are assuming absolute fact with regard to the reality of the glass surface, which is not necessarily the same as what the mirror maker is reading via his tests. I go back to that "where the rubber meets the road" scenario, because I'm a mirror maker, and when I address these issues, I speak as a mirror maker to other mirror makers. For the sake of argument, for the time being I'll buy that RMS is indeed RMS, regardless of RTA and that it can and will tell what you see at the eyepiece. When I read an interferogram, I want to know what the RMS is, not the RTA. I have not studied this issue myself in depth as yet, so I leave myself open to recant at a later date :) However I need to remind mirror makers that the Foucault test can be weak at absolutely determining RMS values. That is why I strongly recommend that knifedge testers use RTA as an additional tool. I'm going to write a bit more about it shortly. CZ

Bratislav wrote: So mirrors with same RTA *can* be quite different. Mirrors with same RMS are *always* very similar at focus. Irrelevant? I don't think so. Bratislav This observation is also predicted by the application of transfer function theory to the imaging of extended objects. If we accept the validity of this theory, than we should also accept the RMS wavefront error as the single most important, measureable criterion for predicting imaging performance. The only remaining variables to affect the accuracy of the predicted performance are then the sampling density upon which the calculated value for the RMS wavefront error is based, and knowledge of the appropriate spectral weighting function to apply. Note that this argument does not say that mirrors with different RTA but identical RMS values will exhibit no detectable differences under the star test; merely that those small differences will not significantly affect the resolution and contrast transfer observed when imaging an extended source. Scott Milligan

I'll weigh in saying Bratislav is probably correct on this. It appears to me that RMS will capture surface smoothness if the sampling rate is much higher, which brings us back to the method of test being the weak point. ("Class, everyone please take out your interferometers, now") At the same time, when it comes to the testing we do I see a difference and importance in the two terms we're discussing, as they are in fact looking at two different things. One is about height of surface error, and one is about slope as calculated at the focal plane.

Again, I still see that both are needed items when it comes to a full diagnosis with the knifedge. For perspective, when I say that ML can do the job by itself I'm directing this to ATMs. Generally you're going to be better than 1/4 wave when you reach that point, with a Strehl somewhere around 90%. Not so bad for early mirror makers if you're actually measuring in that tolerance. My preference is toward a smoother 1/4-wave mirror being desirable over one with a slightly better spherical aberration number that walks back and forth across and out of the envelope.

I'll mention again that we can plot a 1/10-wave mirror that has very steep slopes, and goes comfortably outside ML. I don't find that desirable as measured by the knifedge. Now a 1/10-wave mirror as measured by an interferometer is a whole different ballgame... We of course don't stop at 1/4 wave here in the shop; we essentially try for close to a perfect figure every time. We don't make perfect figures, but we get as close as reasonably possible. Bratislav, you might have more to say about my second paragraph. I do wish to mention here that I appreciate your expertise on our forum. It’s nice to have you stopping by. CZ

Carl claims that figure smoothness is an important ingredient. RMS, by itself, does not capture surface smoothness. Oh yes, it DOES. You just need higher sampling rate. And with under sampled set of measurements, your RTA/M-L will be just as unreliable as is RMS number. We use the SAME SET OF INPUT DATA; remember a rough mirror should not be Foucault measured in the first place. Get it smooth (Ronchi is good for that), and THEN measure zones. If mirror is bumpy and has zones it is simply not finished. All this was discovered by pros long time ago - that is why Strehl/RMS is de-facto criteria used for astronomical optics. Even in amateur hands, with hugely under sampled sets of measurements, RMS has one definite advantage over geometric methods - it contains the information about the erroneous AREA in its calculations. And that can only be a good thing. Bratislav

Dan, I wish to point out here that you're using three tests in combination, which I agree is very good to do, and is just being a good smart optician. What I mean to say is if I read you correctly, you're not relying on a knifedge test alone and an RMS rating put out by the software. My point is the same. I don't subscribe to an RMS rating by a software program as sole criteria for a finished mirror, either. In your case you use the Ronchi test and the star test (performance test) for a smooth surface and verification. Same here. What I'm telling mirror makers is we use RTA as our major smoothing tool, as well as the Ronchi test, and the star test done by the end professional telescope maker.

One more thing I should say to the group who has been following my rants. Please don't get me wrong. I said recently that Sixtests is a beautiful piece of software. It is. It is brilliantly executed, and does marvelous things. My point is a warning to the newer mirror-makers who don't figure using the star test and other tests as backup- I don't believe that the Knifedge test is necessarily capable of determining actual Strehl when the slopes are outside of the M-L envelope. So I highly recommend checking the slopes when you reduce your data if you're shooting for a premium quality mirror. CZ

The point Nils Olof has been trying to make is that some of the fundamental understandings of wave theory can be applied to mirror making for the amateur--to the effect of producing a very useable optic. While it is not necessary for a prospective mirror maker to understand much, if anything about wave optics to craft a reasonably accurate paraboloid, it need not diminish the possibilities of achieving this goal by taking the approach of evaluating a mirror with programs ("Sixtests", "FigureXP"...) that holistically approximate the rms wavefront. I have figured my mirrors to the tune of these tests, along with star testing and ronchi testing at ROC and have had excellent results. I have never used the Milles-Lacroix criterion to decide on the state of affairs nor does what I get at the eyepiece seem to have suffered for it. I have nothing against the promotion of old algorithms that are proven to work, but new methods of interpreting test results based on contemporary concepts of the wave nature of light are what is being offered here. And they work. I believe Nils Olof, and others including myself would like to see fellow amateurs directed away from peak-valley ratings for the sake of clarity and a universal standard (and language) of describing optical quality and what you can expect at the eyepiece. In promoting the use of RMS and strehl ratios that are at the core of data reduction programs based on wave optics, there is no better place than these programs to start.

Choosing a criteria- RMS or RTA (for serious-minded students)

Nils Olof wrote: I didn't mean that a good mirror figured with M- L is anything but a good mirror, and *in particular* I did not mean to criticize Carl's mirrors. You have never criticized my product that I'm aware of. I have no issue with that. I suspect that people who see a Strehl ratio might presume it must come from an interferometry test - this may explain why some people suppose it would be unreliable when coming from a Foucault test (Harold Suiter takes the view that it is, and promotes the RTA as well as the P-V in his foreword to "A manual for amateur telescope makers" [Willmann-Bell]). I would say if it is unreliable it is because it is unreliable, as opposed to because we're used to seeing it stated with interferometry. We have other reasons for the view, those being experience as professionals who use these tools to fabricate mirrors, upon which our reputation depends. With M-L tolerances, depending of how the deviations are distributed, I don't see it as really possible to do worse than about 20 nm RMS (strehl=0.8) but likely the figure will be much better than that. But you could do fractional M-L - for instance, with all readings within half the M-L (or perhaps rather call it Danjon-Couder #1) tolerances, any mirror would be very good or great, and I understand Carl is even much stricter than that with all his mirrors.

Yes, we use fractions of the ML tolerance. I am not an advocate of interferometry - on the contrary, as the members of the ATM list may have gathered, I've tried to defend Foucault on wave-optical grounds, as one of the few tests that (given a well-designed Couder mask) has its wave-optical aspects well controlled enough to ignore. <G While interferometry does take into consideration the whole area, not just a sample diameter, it does not necessarily sample at higher spatial frequencies. And for that matter, it seems to be the practice to ignore astigmatism anyway... I too love the knifedge, obviously, as it is a tool I use every day. However I do my best to remain objective when it comes to test methods, as every test has its strengths and its weakness.

I don't propose that one test is better than another, but rather that each is beneficial for certain circumstances. Evidence of my view is the article I wrote some time back on test method agreement. The problem as I see it conceptually is there is massive amounts of surface area between the center points of each zone. Theoretically we can compute what is going on there via wave optics, but does that necessarily translate into what is actually going on? Also, I'll mention again, I don't know if you read something I wrote a short while back about an actual set of data where a mirror had a plot comfortably out side the ML tolerance and Foucault reduction software gave the mirror a Strehl rating of .96. Based on that one instance alone I have to reject for the time being the ability of the knifedge test to reliably predict Strehl ratio when slopes are outside of the tolerance. Bratislav has said recently that the mirror needs to be very smooth for any of this to work reliably. I agree.

What happens is ATMs who don't necessarily make a very smooth mirror may be led to believe via the software (Strehl ratio numbers) that they're making very good mirrors, when in fact they might well be mediocre. I'm in the position where my reputation is tied to my livelihood, so when I make a recommendation there is a degree of seriousness to it. I don't do it as a matter of entertainment just because I enjoy it, as opposed to playing video games. So I give the best advice I know to the ATM, as someone who has used the tools for a long time. I know that accounting for slopes will keep the mirror smoother, so there is a much better chance for a better optic. And I don't believe at this point, regardless of the mathematical or theoretical aspect, that today's wave software can approach an accurate Strehl rating with the knifedge in anything but a mirror that is already superb. That's my view at this point. If someone is interested in following up and making of study of that one accusation (a Strehl rating of .96 on a mirror that has a plot outside the envelope), I think it could be a good and beneficial study. So, can we be friends again? If you're asking me personally, I can be a growly-bear. Do you really want to be friends? Nils Olof CZ

From what I see on the graphs the mirror meets the criteria. However please keep in mind that we're addressing the ATM who is going to use a knifedge and perhaps an 8 or 9 zone Couder mask on that aperture. What the ATM is going to be doing is not as sophisticated as either your automated system or what Steve is doing. I mean, we start with 180 plots which doesn't give us a typical RTA to begin with, then we do modal analyses, then interpolate, extrapolate, then smooth and so on. Well I didn't get all that exactly correct, but I think you get my point. Let me mention here that I for one really do appreciate what

yourself and Steve are doing, as we do need this kind of work on the cutting edge of ATMing to carry us all forward.

However for this exercise, it would be helpful if we conducted an 8 or 9 zone Foucault test with the eye and the knifedge. Run it through Sixtests to see if we get a high Strehl ratio, then run it through Tex or Admir to see if we have an RTA significantly larger than one (1.0), and then, the hard part- have it tested on an interferometer. There are more potential issues, however, such as overall smoothness of different magnitudes, and so such an experiment would be better done on a smaller mirror. Such a mirror could be made smoother more easily, perhaps, and also be less inclined toward astigmatism. I do recall your mirror is rather thin (as well as large), and I don't know the edge condition, and so on. I suppose there may be other ways mathematically to consider Strehl ratio when slopes exceed, ML, perhaps Steve can figure one out.

My opinion is based on experience with our mirrors and interferometry tests done on them. If I have some time in the near future, I may bring an example before the forum. What evidence I have at the moment, is when the RTA is less than .5 the interferometer and knifedge agree within from zero to one percent. When the RTA reached .75 the difference was three percent. That's comfortably within the envelope, mind you. Then we have Dick Suiter who did a calculation on this forum a while back, where he stated that when a slope went from one edge to the other (not outside the envelope) the Strehl drops to about .92. That sounds about right to me. But to have a mirror with a zone comfortably outside the envelope and the Strehl be in the high 90's just doesn't seem right. I don't think in reality it will be true. CZ

I have uploaded the results into Eason 16" figuring. File named rms_rta.jpg. The Foucault image of the surface and an earlier figuring session Foucault analysis is also in that folder. Doe this meet the desired criteria?

Flat earth society

Michael wrote: I suspect being part of the "flat earth society" (as the mirror group has been called) isn't such a bad thing. Oh, that's classic! Do you recall where that was said? CZ
Re: Flat earth society

Never fear, Richard. I don't take it seriously. It’s when I hear the ridiculous that I like to follow up on it. One of my favorites was Roland saying something in passing about cream cheese being the secret to our mirrors. I don't remember the exact application as he was obviously not serious, but I really fancied it, and signed a couple of correspondences "Mr. Cream Cheese". Stuff like that makes for interesting conversation. I do like the idea of us being compared to the Flat Earth Society. I like being called "Old School" even better “Old, Old School”. CZ PS when the barber cuts my hair, I see little now other than gray. It’s all down hill now... LOL... And to think I studied astronomy and still ended up here. Don't take it too serious, Carl. People the world over know the quality of your mirrors. They are not going to be influenced by a few comedians. Richard

New 14.5" Starmaster with Zambuto

Hi, Jim I wish to thank you for ordering a Starmaster with our mirror. One of the reasons we stopped providing numbers is because people post them publicly for the purpose of resale, and they do it against my written wishes contained in the very documentation they use. We've discussed this issue of documentation on this forum in depth, and I also write about it in the new certification. This public posting of numbers contributes to confusion in the amateur community, because they are derived from one test method, and do not compare well or at all to some others. There are actually several reasons why we did this, all of which have been discussed on the forum in detail. I have to say I seriously doubt that mirrors with numbered documentation will get a premium price over mirrors with the new certificate. Both have exactly the same guarantee for performance, which has never changed from our very first mirror. And both are Zambuto's.

We don't sell our mirrors for any less as a consequence. In fact, the mirrors are now more thoroughly documented and authenticated than before. We have more data on each mirror on file now than when we sent out numbers. I really don't see the value of our product taking a dive in this move (how could it?). It appears our popularity and demand is as high as ever. The reason for that of course, is our performance. It is not because of numbers, and I know you already know that. You bought our product based on our reputation. You did it without a data sheet. I trust that somehow, somewhere, there will be at least one individual, if and when the day comes, that will do the same, don't you think? One individual is all you need to make that sale. And I also trust that they will not pay less money than they otherwise would because of a lack of numbers. People buy Starmasters second hand all the time, and many sellers have lost their numbers, because once they began using the scope and discovered what it does, they forgot where they put those data sheets. I know this because sellers do come to me for numbers on a fairly frequent basis. And yes, it's always when they want to sell it.

Let me state something here, for the record, in the case this is not already understood. Every mirror we have ever made has had a Strehl ratio in the high 90's, and there has never been any demonstrable difference in the performance of any of them. A while back I offered one mirror for sale at premium retail price on this forum. I stated emphatically that no numbers would be furnished, and not to ask about them. Understand this forum has a readership of 600 to 700 people and is not Astromart. Within 24 hours there were seven people ready to buy that mirror. I felt bad that I only had one to sell. So I really wouldn't worry too much about it. Perhaps your best bet would be to think about how you're going to enjoy this telescope. The instrument you have bought will do things no amateur-owned refractor can ever hope to do. It will show you galaxies a billion light years away. It will show you the central star in the Ring, and it will show you the moons of Uranus (at least one of them, anyway). I have seen all three myself, through a 14.5" Starmaster on a night of very good seeing.

Our mirrors coming out of the shop now are every bit as good and in cases even a bit better (technically, from a bench standpoint) than at any time in our history. I wrote recently about the freedom we now have to make very accurate mirrors without having

ridiculous numbers in the public. You might want to go back and read about it. And I'll offer this to you, this one time. If the day comes that you decide to sell that telescope, and you do sell it and feel that you got less than you would have if the mirror had numbers on paper, you come to me and let me know about it. Tell me how much less you think you received, and I'll give you the difference. My congratulations on your new purchase, you're going to enjoy it. Carl Zambuto

Hello all, I have just ordered a 14.5" Starmaster with Zambuto and GOTO. It should be here in 6-8 weeks. Right now I am sitting at my farm listening to the badly needed rain on my roof. Oh well, gives me a chance to say hello. I have been a refractor guy for quite a while and I still love them. But, I have always recognized the quality of a good Newtonian. So, when I decided to get a larger aperture scope I wanted a Zambuto and I like the quality work of Mr. Starmaster as well. My only disappointment is that I "heard", and so do not know myself, that Mr. Zambuto does not provide "numbers" with his mirrors any more. Is that correct and too bad if it is so and Not because I am some egocentric maniac who wants to only talk numbers. I am interested in performance. But, I do recognize that I might decide to move up in aperture one day. The reason I care about getting a mirror with numbers, as I have no doubt about the quality of the mirror, is because of Two words: "Resale Value". If I decided one day to sell my 14.5" so I could buy an 18" (possible!) I would have more difficulty selling mine that you would yours if you have paperwork with the mirror that identifies the numbers. It will command a premium. It will also be more valuable as a museum piece 500 years from now. I'm not as concerned about the museum stuff as I am resale. I am very pleased to be getting a Carl Zambuto 14.5" mirror. Jim Phillips

Testing Mirrors again

Hello, John I'm finally getting to your query. I was waiting to see if anyone else answered this one, but so far, not. I'm not surprised, probably for the reason that many already know my "pet" answer and what I'm about to say, and they may not want to say it for me. The most effective criteria that I know of for determining whether the figure of a mirror is done or not is the Millies-Lacroix tolerance. It is a go, no-go criteria that contains the slopes of the mirror within the diffraction disk diameter. It is easy to check, as it uses the same readings as you took with your knifedge, and there is freeware on the Internet that will show this at a glance. When the slopes of the mirror as measured by the knifedge test and traced as rays fall within the diameter of the diffraction disk, the figure of the mirror is done. At that point there is no noticeable degradation to the image because of the figure. In a nutshell that is it, and it is that easy. Because we're on the subject, there is more I want to say to the entire readership.

Regarding the arguments that go on between wave and (as Michael pointed out) corpuscle theory <grin, I have seen folks react to RTA as if its an "evil" thing. I don't understand this. At worst, it is the foundation from where we came. We don't throw stones at Galileo because he only used a 1.25" telescope, do we? So yes, his telescope is now obsolete, but do we hold up an exorcists cross to it? No! It sits in the museum of science in Florence in a protected glass case (the lens, that is). We continually celebrate

what he did with that instrument. I get some strange sentiment out there from time to time regarding the use of relative transverse aberration with Foucault. I've even seen someone say, "don't trust anyone who uses RTA". Good Lord. If I didn't know better, I would think that what I'm coming up against is a wave of technical arrogance. I would caution amateurs and professionals alike on that issue. It is now well known and documented what happened with the HST mirror and it was a case of technical arrogance, plain and simple. And isn't it interesting now to find out from Michael that somebody actually DID do a knifedge test which said the whole thing was wrong, and the reply was the test was not capable enough to determine that.

Horsepuckey. I'm going to describe this tool (RTA) in a slightly different way, so our student mirror makers out there see it in a different light. A craftsman has an arsenal of tools in his belt. RTA, or relative transverse aberration with respect to the airy disk can best be thought of as a *smoothing tool* in the belt of the mirror maker. It is like the painter having an additional brush, which he uses to smooth over the entire work. This tool is incredibly powerful. (I have yet to read anyone claiming it does not work, by the way.) It is so powerful that it is capable of being the total figure criteria! Notice, John, I actually said when the slopes fall within the airy disk, you're done. So that's how I would want mirror makers to think about it. It is the smoothing-tool for the craftsman. Some talking points on RTA:
1. It doesn't require any additional testing. No other tests are required to learn the results, as it uses the same input numbers from the knifedge test used otherwise.
2. It doesn't require any additional equipment.
3. It doesn't require any additional time. Software such as "Tex" computes both wavefront as well as RTA at the same time.
4. It doesn't cost anything to use RTA. It is absolutely free. You don't have to pay royalty fees to Danjon and Couder, or Adrien Millies-Lacroix, or even Microsoft. The formulas are already in place and exist in freeware programs where you can take a look at it.
5. It is very simple to determine. You just look to see if the plots fall within the envelope.

Now for the bad news, I suspect some of the sentiment about the criteria is because it is more difficult to achieve. Yes, the sad fact is, that slopes are tougher to control the peak to valley wavefront height. But there is a reason for that- it makes better mirrors for the Foucault tester. If you want any more specific or related information John, please feel free to ask. CZ

The problem an amateur mirror maker faces is simple. When do you stop figuring? Or what is good enough for acceptable performance? I have only made two mirrors from start to final figure and on both was faced with the problem of where and when do I stop and call it finished? On the first mirror, a plate glass six inch f/8 (that I started in about 1942 or 3 and my Dad used the fine ground blank to cover a hole in the concrete floor.) When I got out of the army I just turned it over and started again on the blank side. Then I used the ATM books with masks and home made scale to determine knife-edge settings. On the second 8-inch f/6 or 7 I used the same method, but the only improvement was an LED for the lamp behind the pinhole or slit and a vernier caliper for knife-edge measurement (now I would probably use a digital caliper)

But on both, I would test; make a few notes put the mirror back on the lap and try to correct any problems I had seen. Sometimes after a period and retest the figure would be worse and sometimes better. I know I could never reach perfection, but where is the point that is "good enough" to give satisfactory (acceptable? superior? passable?) performance? Any answers? During my working life (thankfully done now) I had the pleasure or pain of supervising design engineers. There are always those in the design office who put out sloppy work that needs a lot of field mods and corrections then there are those who work and labor much longer than needed for a particular job. You can always improve your design but sometime you have to release the design to the shop floor to actually build something. Your shop certainly cannot make a living by drawings on paper (or computer screen now) but must come up with a product that can be sold. If I ever lose enough of my remaining sanity to start a third mirror those are the questions I want to ask. As an after thought: There has never been a greater thrill than turning that first 6 inch to the sky and seeing Jupiter's moons for the first time. The second thrill was to turn it onto the Pleiades (Seven Sisters) and have all those stars hit your eyeball! John Meacham from the high deserts of California 8 inch f/6 Pyrex DOB, home ground, polished and figured.

Autocollimation Testing

Tom, I thought I had all my past postings covered that were not answered, but I forgot about this one, as you did direct one aspect of it to myself. I want to thank you for your suggestion. You must be a very good mirror maker to be using such criteria, but it’s not so good for us. I'll cover some problems that documenting with autocollimation would create. First I agree that it is a rather conclusive test for evidence of a good mirror all by itself. Our first issue is to get a flat that would be as accurate or more so than the product we make. (Think about that one for a while <smile). Also, it would need to have a surface sufficiently smooth to not add visibly to the surface we make under very high resolution. I agree the test is very sensitive.

Next batch of issues- I propose that ANY documentation causes problems between mirror makers as far as competition goes, and will result in arguments between customers. Here's an example. There are a couple of mirror makers off the top of my head who use or have in the past used autocollimation images for an aspect of their documentation. Here is where the argument would begin, it goes something like this: "Your (zambuto mirror) image shows some defects very clearly in those four bands and my XYZ mirror does not". The reply- "Yes, but your image has seventeen bands in it, which effectively shows nothing!" Look around out there and count documentation images with as many as 17 bands.

Here's another one- "Your zambuto mirror image shows surface ripple and mine doesn't". Reply, "well certainly it does, the image is taken at a magnification of eight and covers the whole page, when your image is only one inch tall and has no magnification on it at all!" Look around and see autocollimation docs that have very tiny images, which don't show very much information.

So you get my drift. The question arises, where do we set the sensitivity, and will all providers use a level playing field? I think not, not from what I see going on. Doing such a test, making the photo and the cost of a very good flat will add to the cost of the mirror, but it will not necessarily make a better product. So I agree with you, autocollimation would be a good way to document a mirror. But to be fair, everyone would have to have the same quality flat and use precisely the same settings. And I really don't believe that will happen.

We worked very hard to get out of the "documentation game", and I frankly have no intention to jump back in. I don't know a truly good reason to do so. Part of the reason why we did was because it has many unfair aspects to it, and that's in all directions. I felt the best way to be fair to everyone is to simply not produce numbers. I'm tired of the arguments, I just want to make good mirrors and have happy customers who rely on and love our performance. (I have yet to see any real good arguments about our performance.) The documentation game gets really hairy out there, Tom, far beyond what most ATMs and customers even could imagine. We professionals see and recognize stuff that others won't see, nor should they be able to, because they don't have extensive testing experience. For example I've seen interferrograms that somehow cause the perforation in the flat to change sizes from mirror to mirror. It baffles me how such a thing is done. - Really baffles me. Thanks again for your input. CZ

Don't mean to start a new subject, but in reading through the postings of the last month or so, I kept wondering what carl thought about the use of autocollimation testing using a perforated full diameter precision aluminized optical flat and a selection of ronchi screens to cover the range of F numbers one might test. An additional possibility is the use of a digital camera to keep a record of the test for future reference. This is what I have been doing for years, and it has served to separate the gems from the dogs for me, and to provide a reference, which I can examine on my computer screen any time I choose. The autocollimation test is a double pass (light is reflected off the test mirror twice doubling the sensitivity) technique, which is conducted at the mirror focus rather than at the center of curvature, and I have found its sensitivity well suited to establishing mirror quality both for accuracy and smoothness. The catch is that large diameter precision flats are hard to come by. The reason that I bring this up is that I can see that providing detailed numerical test results to certify each mirror could be a bother for two reasons, the first is that it is a lot of trouble, and the second is that it sets certain individuals into a search mode for the mirror with the best (strehl?) or some other ghost number, and it puts carl in the position of trying to satisfy people who do that. A quick autocollimation test with digital photo would show mirror quality at a glance, but would not necessarily provide a number. More a qualitative than a quantitative evidence, but it clearly would show that there were/were not defects, which is all that I want. Tom leech

New 14.5" Starmaster with Zambuto

Jim, This is going to be really tremendous. You're a long time observer, like Geoff is. You dreamed of the state of the art aperture system in its time, the Cave 12.5". The scope you have just bought is actually portable, and will have every bit of the performance that

you imagined all those years (in truth it will have even more). I'm very pleased to have the opportunity and the privilege of participating in the accomplishment of such as long-time dream. I'm looking forward to hearing of your impressions over time. Carl

Hello Carl, An excellent reply with which I completely agree. When I started observing back in 1965 I became a lunar/planetary observer and admired many visual observers of the nineteenth and some, like Alika herring from the 20th c. My dream was a 12.5" Cave-Astrola Newtonian on GEM, like Herring, which I never purchased. Now, I will have a 14.5" Zambuto Starmaster. It's going to be a lot of Fun. And, of course, if I ever want larger aperture I may not want to sell the 14.5"! Thanks for the kind and detailed reply. You're right I don't need the numbers. Jim Phillips

New 14.5" Starmaster with Zambuto

What you may be struck with Jim is how much aperture you have via actual performance. Because of the contrast, the scope is going to perform like some (many) scopes by other manufacturers of larger aperture. We have many reports of 14.5's specifically (as well as other sizes) who show detail only seen otherwise in larger sizes, and in some cases larger scopes, which do not show the same amount of stuff. We do have reports of 14.5's actually outperforming 18's on deep sky, for one example. The reason is the contrast is so high, that much fainter things pop out. Being a refractor owner as you are, I'll be interested in your first impressions when you take that first look, even at low power. As you already know, contrast has a particular "look" to it, to the veteran observer, which is both pleasing and satisfying. That is our goal, to make the scope seem like a refractor as much as possible, when it comes to contrast. Cheers, CZ

Hi Tom, I do believe we may get some good seeing here. And, my initial thoughts are to go after some Deep Sky stuff using the GOTO. While 14.5" is on the smallish side for many Deep Sky buffs, it will be significantly larger in aperture than my 10". Of course if Jupiter is nearby and high in the sky I might check it out if the seeing is good. Not sure about imaging. I do want to do some visual observing. But, who knows? I do know this. I'm going to have fun! Jim Phillips

Mirror Polishing and Figuring

John, One of the very common issues I find with ATM's is they often start out attempting non-standard work for their first experience. You're working a disk, which has a thickness ratio of eleven to one. Understand that even with the skill we have here, we have no small mirrors at 11:1 that we do in this shop. Our thinnest mirror at smaller than 18 inches diameter is 9:1. So it is no surprise that astigmatism is coming up as a repeated issue. Now that you've been duly scolded, I'll give you some pointers, and we can look at the situation.

First be sure the back of the mirror is ground mechanically flat. We check ours with a spherometer, and get it within a few ten thousandths. Even one thousandth is probably

fine, but the idea is to get it uniform and close to flat. Next, be certain your table is flat. We grind our tables as well. Two of our machines have cast iron flats for tables, which rust up over time, so every once in a while we grind the tables for a few minutes. Other machines have interestingly enough, particleboard tables that are laminated together. We used to just put several coats of Varathane on them, but they would get pinholes and swell up. Then we decided to try pouring a resin top.

This is now the table of choice. It is very lightweight by comparison, the cost is minimal, and they don't seem to warp. Our smallest tables are three layers thick (2.25") and our largest tables are 5 layers thick. The layers of particleboard are glued and screwed. The whole thing is epoxy painted except for the top, which has a 1/4" thick resin coating. Then we grind the table just like we would grind metal or glass, and get it flat to within one or two ten-thousandths. The way we hold the mirrors now is with between three and six stays around the edge. We have upright outriggers around the edges, through which we have a bolt. Some are nylon bolts, and some are standard bolts with nylon furniture pads on them. But the mirrors are held around the edges with nylon pads of some sort. Go to the photos section, look for Shop Tour and look at polishing the 24".

The mirror is held loose between all the pads. It can float around, with movement overall about the thickness of a piece of paper, so you can actually spin the mirror a full rotation by hand, but the slope is very minimal. It is only what is required to be able to rotate the mirror by hand; otherwise it is as tight as possible. In any case, do not bind the mirror. We also put a pad under the mirror. We used to use a lot of 3/16" indoor/outdoor carpet. We now have come to also like a thicker carpet padding that is rubber. We use those more on larger mirrors than smaller ones. But you do need some kind of pad to float the mirror.

You can't bind down a thin mirror under any circumstance. You WILL create astigmatism when you do that. So look at the things I've mentioned, and see that you have their equivalent, and see what happens. Beyond that, we will have to get into actual polish technique. It is indeed possible to polish out astigmatism, but not everyone knows how. We have an unusual technique that we developed over time. It’s very specific, and not easy to explain. So see what you can do first, with a properly supported mirror blank. By the way, one other way to do it when you're working a thin mirror is to just do hand polishing with a full diameter lap, mirror on top. In the few instances where we do very thin mirrors, we wind up doing that after the mirror is polished out. We do it by machine with a jig that holds the mirror loose, but it is the same effect as doing it by hand. CZ

Hi Group, I am new to the group, and over the past few days I have been reading most of the posts on the group. There is a lot of information for the new mirror maker and thank you all for posting these tips. My project is polishing a 12" mirror 28mm thick low expansion disk with a focal length of 1200mm. I've always wanted to build myself a high quality deep sky telescope. I have built myself a look alike Mirror-O-Matic polishing machine but with a lot more adjustments on it. The speed of the spindle can run from 1 rpm up to 100rpm and the same for the arm strokes. The problem I am having is when I polish the mirror to a sphere I have astigmatism, which of course is bad. I have held the

mirror with 3 clamps at 120degrees tight and slack, glued a metal bar on the back of the mirror (in the center of course) and held it with wood via duct tape and 3 clamps holding the wood. All three produce different amount of astigmatism but it is still there and too much to start parabolizing. How do you hold your mirrors to polish them and figure them? Regards John

A Shop Visit - Thank You Carl

You're quite welcome, Preston. The pleasure was certainly ours. And your dad was wonderfully interesting as well. Having a world authority on gyroscopes that knows more about the space probe than the S&T article provided was no small thing a real treat for us to host guests both of whom are of such high caliber. Carl Just wanted to let you know what a pleasure it was to meet you and Chuck. We really enjoyed our time with you both. Cannot remember when I've had that much fun discussing something we both obviously just enjoy. Email still??? Working??? I don't know. Thanks Again for the tour, time and lunch. Very Best Regards, Preston

You're far too observant for my comfort :) Usually I can do the work right in front of an ATM and they don't "see" what they're seeing. I guess you were ready for the information. Now let's talk about that red wine you brought... CZ -will contact you offline Preston wrote: Thanks Carl. After our visit, dad and I would spent the mornings discussing fabrication techniques for off axis parabolas, the afternoons on testing theory & the mathematics involved in parabolas and hyperboloids and the late afternoons designing a little gyroscope for improved down hole surveys and then of course a little red wine. Our talks and visit with you are already paying off. Most every thing that I was unsure of prior is going very well. The figure on the 12.5" f4.5 is coming right along. The outer edge going down slowly with the overall smoothness is just incredible. Oh, yes smoothness...well you secret is safe...I do observe very well when around experts like you and Chuck. Without even realizing it, picked up your little move {grin :<)}. But had you mot made mention of it months ago on the form, I'm not sure that I would. Very Best Regards, Preston

The door is open. We entertain guests, but we don't "spoon feed" as this is not officially a school. You can ask questions, and we'll do our best to answer. But the questions have to come from you, as that will be the information you're ready for. Red wine is always welcome too, for after work. Carl Now let's talk about that red wine you brought... Carl, I have plenty of red wine around here for you to sample. Maybe I can come up for a shop visit sometime. Hopefully after a few bottles you can divulge some of the secrets to me. Robert

Mirror Polishing and Figuring

Good question, John. Both surfaces in question are hard surfaces, those being glass and metal, or glass and wood, etc. Whenever two surfaces meet they will always touch at three points. I don't care how flat they are, they will always touch at three places because

there is no such thing as perfectly flat, if for no other reason than expansion and contraction during polishing. Three points determine a plane, so that's why the number is three. It will find a triangle. Well, when you have a mirror resting on three points it will tweak the shape of the glass ever so slightly (We're talking optical tolerances, here). You will then polish in astigmatism sure as the day is long. To not have that happen you HAVE to float the mirror on a pad, there is no other way that I know of. The pad will even out the very small discrepancies between the two surfaces, as well as small changes due to expansion and contraction during temp changes from the polish, the water and so on.

We are not rubbishing the flat surface, but rather capitalizing on it. We must have a flat surface to begin with, and then we give the mirror a padded surface to float on. The pad provides *uniform* support to the back of the mirror, which is a necessity for non-astigmatic polishing. But the two substrates need to be flat for this to work. For example if you put a BB under the pad in one place and raise the mirror just a tiny bit you will see astigmatism go right in. Then remove the BB from under the pad and the astigmatism will disappear. Cut a pad the diameter of your table and put it under the mirror. Short-nap indoor-outdoor carpet works well for smaller mirrors; I think ours is 3/16" thick. It has a rubber back and a short loop on the face. CZ

Dear Mr. Zambuto, Thank you for your answer, but something I'm puzzled by is the following statement. We also put a pad under the mirror. We used to use a lot of 3/16" indoor/outdoor carpet. We now have come to also like a thicker carpet padding that is rubber. We use those more on larger mirrors than smaller ones. But you do need some kind of pad to float the mirror. Why must you have some kind of padding between the mirror and the holder? Why grind these two surfaces to certain accuracies then rubbish it with rubber or carpet. I don't understand. Sorry for the questions but I like to know how things work before I go ahead and try them. Regards John

Mirror Group Birthday

Yesterday went by without a thought, I forgot all about it. I do have a screensaver that has an aquarium with a crystal-looking clock in it with the day and date, and I did note when it said July 1, but I forgot all about the birthdate of the mirror group. So, Happy Birthday! If anyone has any remarks or reflections this might be a good time (I mean excuse) to wax long about it until everyone gets bored out of their minds. We are now two years old. So we're at that stage of development where we first realize that we're not the center of the world, that in fact there is indeed a world around us where there are other individuals, and that we're not more important necessarily than anyone else. No wonder they call it the "terrible twos". Frankly I don't like the premise at all. I'm going to go off now and throw a tantrum... CZ

Lifetimes of Various Coatings

I'll add a bit more to the old posting. You asked about various coatings, assuming there

may be a difference. Such a premise has been insinuated (or should I say outright marketed) by one major scope maker, for example it was said by that scope maker that enhanced coatings outlast others (standard coatings). That is a very broad stroke, whose fallacy was clearly demonstrated in real terms, recently. A whole slew of enhanced coatings sold by that manufacturer failed very quickly and those coatings had to be redone with the cost covered by the seller. In fact it even resulted in a switch to a new company to have the coatings done. The quality of a coating is all about the care, skill, and workmanship of the coater. It is not a slam-dunk process by ANY stretch. The same thing that applies to mirror-makers applies to coatings, it is very much art and science, and once again, reputation is what it is about. Getting a good quality overcoat that doesn't cause detriment to the performance of the mirror is a major issue, and is what separates the good coaters from the mediocre, and from the bad. So I'm not going to list different types of coatings. Some processes are even proprietary and the coater doesn't say exactly what it is.

With respect to longevity, which is what you have asked about, I'm going to throw them all in one bag- good ones, mediocre, and bad. The bad ones will fail quickly. I have stripped a coating that disappeared in three minutes. I have also stripped coatings that took three hours. The three-hour ones are made by Spectrum, the company we did use. If you're near sea air, the life of the coating will likely be reduced. Washing more often may be in order, because there will be salt in the air, and you know what salt does to metal. You will certainly want a coating that has an overcoat. One coating that is well known does not. It’s a good coating, but not so good for the ocean air. Again, the best answer I can give is from one to ten years. There are just too many variables to say otherwise. CZ

Which are the average lifetimes of the various coatings available for primaries, assuming a rather mild sea climate, about 50 observations a year and taking good care of the mirror? Richard

Your original query didn't solicit specific recommendations. We used the Spectrum coating and it is no secret, so I can mention them. We don't presently fabricate mirrors over 24 inches so I don't personally have a coater for that size range at this time. If you actually have a 24"-plus mirror that needs coating and you need a recommendation you can contact me privately for some {limited) input. CZ

If the mirror is up to 24", Spectrum is the obvious choice, but who to choose in case the mirror would be larger? Richard

How Much Overcoat

Michael, You wouldn't expect to hear this from me, but I think in truth there is almost no limit to the amount of overcoat or number of coatings that can be used and still maintain performance. ***HOWEVER*** that is assuming a very high-end professional process, such as in the most expensive industrial applications where measurements are taken and chambers are calibrated, and so on. Such processes are totally foreign to the amateur industry as far as I know, and that is how it should be. It is another league. For example, I

have (vague) recollection of hearing of a process whereby a mirror was simply layered with dielectric overcoats, so many of them that total reflectivity was achieved. There is no aluminum layer underneath, only the dielectric layers. The number of coats might have been to the tune of 50 individual layers. The problem we get into in this industry is quality of chamber, loading, and how it is calibrated.

I would never venture to be a coater without strict calibration, working with an optician to calibrate the process to the level of coating thickness and accuracy that I want to achieve. For example regarding uniformity requires larger, longer chambers are good for more uniform coatings. The very finest uniformity would naturally occur when the mirror is coated from a charge deposited at the radius of its curvature. In reality this is not usually going to occur, because of the extreme expense, due to the extreme size of the chamber. So to answer your question, in theory there is no limit that I know of. In practice, however, in this industry my rule of thumb is, put on only as much as is necessary to do the job. Anything more might screw it up. CZ

I was wondering if you (or anyone) have an idea of just how thick an overcoat can be before it affects performance? Michael Gilbreath

Michael, Thank you for the Hubble mirror information, very interesting, indeed. Yes, it appears that "thin is in". I didn't necessarily mean Spectrum, but I think it is correct nonetheless. My understanding is that 1,300 angstroms is the norm for a standard AL coating for this industry, and I think that Spectrum uses that amount. I might offer here that its possible one reason this is the case is because amateur astronomers have a habit of holding their mirrors up to bright light to look for pinholes. "And we can't have any pinholes, right?" So it is possible that coatings may be laid on thicker to keep our inspectors happy. Personally, I'm not concerned about a reasonable number of pinholes. They are in fact normal. Less is good, but I don't get terribly critical about it, provided there are not thousands of them, clearly showing a pattern of how the mirror was cleaned. Thanks again for the Hubble info. Good to know. CZ

I am assuming that it was Spectrum that had the 1300-Angstrom thick coating. Did I misread that? Michael

Black Rouge Polish

Adding a new polishing compound with different characteristics should for the major part show its results right away with the lap that you have, just as it is. I would think any residual effect of the previous compound would be minimal, but perhaps not non-existent. My suggestion if this is an issue for you, is to brush the lap with a wire brush. We brush our figuring laps regularly anyway, as a matter of course, for different reasons. Using a (clean) wire brush that is only for the purpose of brushing laps can remove the existing surface and expose all new pitch.

Right now we use the uneven-cut brushes, they tear away at the surface pretty aggressively. If you're concerned about standard brushes (rust) you can also buy stainless

steel wire, or brass brushes. All are available from the hardware store. After you remove a layer of the surface with the brush be sure to give the lap a good pressing. And after you experience the action of a lap that has been well brushed in two directions 90 degrees apart and pressed just the right amount of time you may never go back again to an un-brushed surface. CZ

Figuring & Frequency of Cold Pressing?

Any time a lap is removed from a mirror after a session it is *always* pressed again when put back on the mirror. If only for a minute or two as a touch-up, it must always be pressed. When the pitch is drying off, and the mirror is drying off, heat is leaving their surfaces and things start to change shape. Remember you're dealing with an optical surface, which is on the order of millionths of an inch. Generally a lap will tell you when it's not in contact, but not always so. If the curve is different but uniform, you may not know it until the figure tells you otherwise. Once you have your curve for the day (longer presses first thing are good), a touch up of a few minutes is usually fine. But always repress when reintroducing the lap to the mirror. I learned that on my very first mirror, and have never done otherwise.

Other than that, we have a saying here in the shop that was coined by yours truly a long time back: "The glass will always tell you what it needs". In other words, no matter what you do, right or wrong, the glass always lets you know in no uncertain terms. The glass always has the final say and the last word. It is the final arbiter. CZ

Carl, One of the things that I don't believe we discussed was how one determines how often to cold press when you are figuring. My figuring stints are between 10-20 minutes depending on how much work there is to do in a particular area & what size lap I'm using. Smaller laps, I work shorter durations and larger typically longer. The laps seem to stay in good contact for 3+ sessions, but I'm just curious. Just finished the overarm modification to your style. Now to see how it affects my ability to more accurately affect the areas that I want to work. Best Regards, Preston

We have another saying in the shop, "The mirror isn't done until the edge is done" If your edge is still under corrected and you have a hole in the center, generally you can wipe it outward. (If the edge is done and you have a deep hole in the middle, you're screwed, unless you know how to employ more exotic techniques that are too much to explain here). Your largest lap, at 60% diameter of the mirror would smooth the entire surface and deposit the greater correction at the edge zone, and leaving less correction toward the center. The stroke would be full overhang, with relatively small offsets. Large laps make smooth mirrors, but only down to a certain diameter for each size lap. (When you get down to an area that is too small for a given lap, you just produce a kink in your zone progression). And laps that are too small for a given area dig holes (when not used properly). There is an ideal size lap for each diameter of surface area.

The trick is to learn when to switch sizes and how to blend one diameter, or zone, into the next. Using offset can blend the transition point from one size to the next. -Smaller laps

act like larger laps when offset from center. When you get all that down, you'll be an aspheric specialist. CZ

Thank You Carl, as you have said, if you know to ask the question...you are ready for the answer... I am really liking the new overarm design...but I dug a hole in the center on the first 10 minute stint...Yes I know...but am still learning... Figure in the center is now very nice...if I mask the outer 2" we would be great!!!! We'll start to work on that tomorrow...I now understand why you go from outside to inside :) And why you wished me luck in correcting my problem... Best Regards,

Birth of the Spreadsheet

I'm curious about something. How do ATM's decide where to remove glass when parabolizing a mirror? What software if any is being used? I've had a request concerning the software we use, and I'm wondering what is out there that ATM's are successfully using to decide how to attack each figuring session. Anyone care to give us an indication? I have something in mind. For a long time I looked for something that would help the production-based mirror maker (such as someone teaching a class) what to do quickly, and the most straightforward, for any given scenario of surface figure. I found the current available stuff lacking when I got into it, so over a period of years we designed our own. I'm wondering if an Excel-based spreadsheet designed by ATM's for public domain would be beneficial any thoughts out there? Students? Veterans? CZ

Well, Preston, so far no one is banging the door down. We took a look at Figure today. Yes, it has a fully functional wavefront profile with a COC constant that can be changed to show the mirror from any focal point/figuring point. Good stuff, well executed. At the same time, as you pointed out it doesn't seem to have RTA, nor does it tell you what size lap to use or where to place it, nor does it show you an astigmatism plot of your mirror at any time during figuring. Its okay for the amateur, but the serious student could have better tools at their disposal. We'll see if there's any interest. So far folks seem to be content with what they're doing. I guess I don't need to worry about anyone catching us any too soon. CZ

Hi Carl, We are using Dave Rowes "Figure XP". It seems to work well but does not include the Millies-Lacroix tolerance or any attempt to guide one to the lap size and position of the lap for a given correction. It does provide a nice "Surface Error Analysis" graph indicating the surface profile above spec in nanometers. I find the biggest problem with knife-edge testing with a Couder mask it trying to determine when the zones under test are nulled. My eyes just get TOO strained. But, I have rigged up a web cam "740 ToUcam Pro" behind the knife-edge and use the K3CCD software to acquire the images. The image once acquired can be measured for 256 gray scales. By taking several images with different offsets, I can get the gray scales of the zones under test to match within 1-2% of full scale repeatedly. This relates to a knife-edge offset tolerance of .001" in 3 sets of acquired images. And yes, I have checked the accuracy of the gray scale by subtracting out the dark frames and flat fields. I get much more repeatable results as indicated above than I ever could with my eye behind the knife-edge. I find this much easier than trying to figure out exactly what is going on with a Ronchigram. But still, once one knows the

surface errors, understanding what a given lap will do is the next curve. Hope we get some interest. Preston

Thanks for your reply, Steve. I too used Admir in the early days. Then I found that anything greater than 1/4 wavefront error could not be graphed, as I recall. So I was in the dark for a surface profile until I got the mirror better than 1/4 wave. But I did cut my teeth on Admir. We still use the same core math today. CZ

I started out mirror making using ADMIR by Dick Suiter. I believe it was the first program that would show you where glass should be removed. It's an old program but it works very well and I have never felt a need for anything else. Steve

Preston, We won't leave you in a total lurch. At the same time, there is no substitute for experience, which does include trial and error. If mirror making were straightforward and simple, everyone would make a great mirror all the time. Opticians in training here study for years, to become adept. No, the group likely doesn't realize what is being offered. What I've noticed is the folks who are interested in our software are those who have visited the shop. They see the progression, and they see us electronically demonstrate the procedure. They see how the software integrates with the process and how efficiently the software is geared specifically toward fabricating the mirror and THE LIGHTS COME ON. I think what's going on is, generally folks have no idea what can be done until they actually see it. The problem is, many mirror makers simply don't realize what they *don't* know. There are many levels to this thing. One doesn't realize what is beyond them until they stand on the next hill where they can catch a glimpse into the distance. I know it was true for me, at every step of the way. But the difference between the “next guy” and myself is I always wanted to know how to do it better. I agree with you. "Status quo" doesn't cut it. I'll write more on the power of the spreadsheet soon. CZ

Status Quo is never good enough Carl...I do not think the group realizes what you have offered. Yes, one could learn by trial and error, a lot of trial and error, but with the chance to be tutored and coached by a master ...well we can only hope to get a better response... I for one am getting tired of trial and ERROR!!!!!!! And as you have so simply said, there is nothing really out there to help one learn the other than trial and ERROR!!!!!!!!! Best Regards Preston

Richard, The answer to your question comes in the application of the software to the work. That comes later, down the road. If all goes well we will get there one day. Also, there's a whole lot to what you're asking, in fact many facets of it. Not a simple answer. So do keep the question in mind as we go along. Carl

How to Decide Where to Remove Glass When Parabolizing

Carl, Count me in. I may never make a mirror, but I would still like to learn more about the integration of your software into the fabrication process. Without divulging any proprietary secrets, how have you optimized the software to maximize the efficiency of individual sessions? Richard

Preston asked, and why is it that you have your optics on a lower level to test i.e. below level and lower than your boxes in the other room??? It is convenient to have the optics lean slightly backward, so as not to tip over forward. If you looked at the stand for the 24" at 200 inches away, you may have noticed it was precisely the same level as the source on the tester. Those mirrors we want to sit exactly vertical on edge, to keep the flexure uniform, because of their weight. That stand has a clip on the top to prevent the mirror from falling. But otherwise it stands on its edge by itself, floating on the pad in the curved base. And did I notice that you do NOT touch the surface of the Mirror??? Wash and rinse in the sink and let to dry... Again, your powers of observation are strong. I never touch the surface of the mirror or the lap. That can deposit oils that could cause localized deformity. Ps. I dug another hole in the center today after reviewing the past progress... a 5" lap off COC from COC to 1.25" with a stroke to the 8" diameter...in just 10 minutes...just another 1mm cubed, micro meter. Without measurements I'm unable to make any specific comment at this time. I have to see the surface to make any recommendation. Carl

Yes, the response is better. I think it may be worthwhile for me to make the effort. First, Eric, its tough for me to answer your figuring question, because it depends on your overall strategy. We correct from the edge to the center. When a zone is completed (hopefully with a smooth percentage correction from one zone to the next) we zero it out on the line and look to the next zone in. So we would move the COC constant so the completed zone is on the parabola. That would then say what glass has yet to be removed and where (it would be inboard from there). If you need more than that say so, and maybe others or myself can be of further help. When we get an ML graph established with the spreadsheet I'd provide you with some revealing glass removal strategy.

Carl' Offer

Ok, on to the offer. Here's what I have in mind, gang. I have this need to teach, from time to time. I taught telescope making for four years, had a great run of classes, and finished 65 telescopes successfully. Only ever lost one student, it was the first class where they didn't have to pay anything. The student came back years later looking for his glass, but I had donated it to a handicapped student who was unable to complete their own (I had finished the mirror myself). Okay, so that was more info than you wanted to know, on to the subject. I don't want to just give everything away. I would like to teach it and be involved, if there is a core group who wants to build a spreadsheet. What I have in mind is, we would decide someone who would head it up, or a couple or three who wants to work together. These folks should be proficient in spreadsheets to some reasonable degree (its not rocket science in this case). We would discuss a concept such as ML and I would provide the text and the formulas.

A series of cells would be created with a graph and a core template would be birthed. You will build it. You will customize it, and you will call it what you wish. It will be public domain, owned by the amateur community. As time goes along, it will come to the place where it does everything we have at our disposal here in the shop. The purpose is that by the time it is completed you will all understand how and why it works. Many

people originally wrote it. Most of the names are Millies-Lacroix, Texereau, John Hall, Dick Suiter, Charles Smith, and Carl Zambuto. It has components from all of those authors in it. You will recreate it, customize it, and grow it. One beauty of a spreadsheet is it is always customizable. There is no limit to the number of functions and modules it can have. It will not remain static, but rather it will be something that the ATM community can work on and refine, and make quite remarkable. I can give it the start, with your help.

In the future, I would expect it would become much more than it is today. So, if you're game, decide among yourselves who wants to head it up and I'll start getting information to that person. One more note- I do expect this to be a fairly long-term project. Its something that can keep things interesting, allow me to do some teaching, and cause ATM's to understand how it works and why they're doing what they're doing. I'm in it for the fun of it, for the learning (I expect to learn more than I teach) and for something to keep a few of us occupied for a while. CZ

Hello All, I'm not sure Carl was offering us his software... but I learned a tremendous amount about the second order things and which direction they tend to make figuring go from a prior post which will save a tremendous amount of trial and error. If they could be roughly quantified in terms of percentages it would be even more useful. I use several laps that are about 3/4 inch different in size and I think I understand their primary effect but this post made things much clearer. You asked what we use for software, I use figure XP and just eyeball the M-L criterion on the graph. Two specific things that Carl or the group members could help with confuse me: The first is how to use the change in COC slider to help think about the next step in figuring. I understand what it does, but it is automatically set to the place where the overall error is smallest which seems like the place one should start. What is it used for to help plan the next step? The second is how the particular high or low zones in the glass change the figuring action. For example, does a raised zone cause less action outboard of the zone? Sometimes it seems to but it maybe that is due to a slightly different "best" COC. Inquiring minds want to know, Eric

Okay, Looks like there's going to be sufficient interest, based on such a response in a short time. What you might do, James, is analyze what will be coming across and if you find useful concepts you could convert the capabilities over to Figure, which is a very beautiful program, BTW. What we plan to do here is much more simple. Each user will have direct access to every cell so they can comprehend as much as possible what is going on. Most of you know by now I like simplicity where possible. Tom Karpf indicated a long time experience with Excel and Lotus. BTW my mentor John Hall uses Lotus, which is the format a lot of early material came to me. Tom, if you wish, you could be the point man. I'll direct initial material to you. Okay, I'll get started shortly. I'm going to take a long look at our spreadsheet and decide where to begin.

ML First

I think what we may do first is work a very simple setup for ML because it provides a lot of bang for the buck. It is very simple stuff. We also have to decide a format for passing

the material along. I'll work on that, too. One more thing, I have to confess I left something out. We decided a long time ago in the interest of simplicity to create one spreadsheet for a particular number of zones. We can look at that as a group as we go along, perhaps the advanced programmers would like to incorporate full functionality into one document, but I don't know that it is necessary (it will be much more complicated).

Number of Zones

What I need from the group to get started is a decision on a first doc of how many zones to incorporate. Those who are involved in mirrors right now perhaps could get a consensus of how many zones will benefit the most of us. We have docs from four zones up through nine that we use to do all the work. We have an eleven as well, but don't use it so much anymore. I'm thinking that any number from five to seven would be a good start. Meanwhile I'm going to figure out how to convert the article from TM #6 (Stalking the Wild Paraboloid) on the ML tolerance to text, and get the info to the group. Will lie out the first set of spreadsheet cells as well. CZ Since I wrote the user interface and code to convert Dave Rowe's Figure for DOS into FigureXP, I'd be more than happy to contribute in any way I can. If the end result is something that could be included in FigureXP as a tool to help guide ATMs during figuring, that could be pretty neat! Take Care, James Lerch

The Mirror Makers Spreadsheet

In the files section there is a new folder, "The Mirror Maker's Spreadsheet". It is my intention that materials for our new project will be put in that folder. The first item is a five-page article from the (now defunct) Telescope Making Magazine, issue #6. What I did was scan the pages and save them as a Photoshop jpeg file. That was the best format I could find at present, to keep the file sizes reasonable. You should be able to read the pages directly as they load onto your screen. (My AOL browser looked good.) If anyone has any trouble, let me know. My suggestion is for ATM's who have interest to read this article and do your best to digest it. The purpose is to understand why we're doing what we do, and how it works. Then when it is put together in the spreadsheet, you'll understand what you're looking at. Tom Karpf, our spreadsheet project specialist will be unavailable for the project until Wed. I'll still be uploading files and making announcements, and I expect he will get started on the spreadsheet next week. Meanwhile, next I'm going to prepare some initial layout. Feel free to discuss the article, ask questions, shoot holes in it, or what-have-you. Have fun, CZ

I appreciate your sentiments, to be certain, but this may all be overrated. At the same time, history will indeed be the judge, and there is nothing we can do about that. Keep in mind also that we're talking about the software. It is an important and integral part of the equation, but not anywhere nears all of it. It will, however, press more questions that do indeed lead the way. CZ

Thank You Carl, as someone else already stated, "This is history in the making", and with

a master offering to teach...this may well be a turning point in ATMing, at least as far as mirror making goes.

Figuring Laps

Robert, We used to put about five mild scallops in the edge, but don't anymore. It doesn't hurt anything to do it, but it seems not terribly necessary. Star laps are okay, but again, not entirely necessary when it comes to machine work with tool on top. I don't know how deep your scallops are; I hope they're fairly mild. One-fifth inch overhang with a star lap will leave the edge behind badly once the correction begins. Also, ten minutes will do just about nothing. There is no surprise there.

If you want to see some correction in the edge zone, set your stroke overhang to 25% of the lap diameter, and work at about 20 RPM eccentric speed. I would say put in about an hour before you begin to see much at all. Don't leave your offset from the center static. Change your offset a bit every once in a while, such as every few minutes. Find about three positions, anywhere from 1/4" to 1/2" apart between the positions. That will give you a basic idea of what it takes to begin. It takes a full day for Chuck to rough parabolize a 12.5" mirror to about 80% to 90% in the edge zone, sloping off toward center. The machine is running most of the time. It is many hours to put the majority of correction in a mirror. And another notes to the group- those of you who are attempting to figure with a machine, mirror-face-up and lap on top. It is no different from doing handwork by the same method. One relatively short resource is the article on Mel Bartel's website on figuring large, thin mirrors. The basic technique is the same, with the stroke, the offset, and so on. In its purest form it is precisely as the article spells out, no matter what size mirror. The principles are the same. CZ

Carl, I was wondering if you use shaped figuring laps? I have been studying all the posts on how to figure using a machine. This was one thing that I was wondering. I am just trying to work out how to get a figure in a 10" that I am working. Currently I am using a 6" star lap. I ran it for about 10 minutes last night and did not get anything to happen. The Foucault still looks spherical. I was using the lap slightly offset from center and running it edge to edge with about 1/5" overhang. Robert

John, I think your approach is rather good. We do essentially the same right here in our shop. For an example of the capability of the Ronchi test in the hands of an experienced user, I've watched Mel Bartels take a group of mirror makers with 16's almost to completion (and close enough for some) with his Ronchi program. It’s amazing to see him work, and how adept he is with that method. When we get this thing going, my hope is that the finished spreadsheet will give you back all the functionality that you were used to with Tex, and then maybe more. Again, we need some feedback from the group on zones being used presently, as well as some discussion on the article that was posted yesterday. (Students, some effort will be required :) CZ

Chris, in the telescope making class I teach I primarily use both the Ronchi For Windows and a Ronchi tester. This is mostly due to the simplicity of the test and in my experience

this has been easier to teach the students how to interpret the test, especially those making their first mirror. When I am figuring a mirror, I tend to perform Ronchi tests until the figure is pretty close. After that I will use a Foucault test with a Couder mask. Initially I used manual calculations, and then I used the software application "TEX", and now use FigureXP since "TEX" does not work properly on my WindowsXP computer. If I were to make comments on "TEX" vs. FigureXP, I like the way FigureXP works best, but miss the capability that "TEX" has to generate zone size calculations. I really liked this particular feature. Currently I am working on a 24", a 22.5", two 18", two 16", a 12", a 10" and a 5". In our current class, there are 16 students with mirrors ranging from 6" to 16". John R. Zeigler

Preston wrote: Ok, "Stalking the Wild Paraboloid" is full of interesting info. A few questions come to mind.
1. In the determination of the diameter of the diffraction spot and thus its use in determining the upper and lower limits within the good window, it appears that the distance above and below the optimum line would be equidistant. However in the graph on page 21, the upper and lower lines are not an equal distance from the paraboloid line. Care to comment? The graph in the article includes the parabola, which moves upward from center to edge. So the places equidistant from the parabola will show up on the graph as different values, top and bottom (as per the chart on page 20). Points that are in actuality equidistant from the parabola will appear to have different values when you consider their placement on the X-Y graph. Perhaps its an optical illusion, but it does seem to me that by observing the graph itself the points are in fact equidistant from the parabola. Looking at the chart from which the graph is made, it might not at first observation appear to be so. And this brings up a point. In most software today, we remove the parabola from the graph, both to conserve space, and to be able to open the graph up more and see more space (detail). When we create the ML aspect of the spreadsheet, the parabola will be removed and appear as a straight line. The function will be the same.
2. I know that in working the figure you work from outside edge to inside and this is also recommended on page 23. Do you test also from outside to inside, as they refer. If so, how does one know the offset at the outside to enter into the calculations? We measure our mirrors from center to edge, and then back again to center. In functionality it has little to do with assigning offset values. This brings up the topic of the "center of curvature constant (COC)". There are two factors here- the numbers spit out by the micrometer not starting at zero (they don't need to), and the desired offset from the average norm achieved in the final set. The COC constant is a number, which we add to the full number set, to balance the measurement set over the parabola. Of itself, the number is meaningless, except that it simply moves all the plots simultaneously the same distance up or down. We can do this very easily with software. Graphically, in the article, that function is done mechanically, by sliding a transparency up or down over the graph. Mathematically, as in software, the same thing can be done with the COC constant. Programs such as Figure, when changing the focus point and thus how the surface appears (via the slide bar for one example) are doing precisely that. They are changing the COC (center of curvature) constant. Your measurement set doesn't change, but rather the entire set is moved closer to or away from the surface of the mirror, mathematically.

It doesn't change the shape of the mirror, but rather the appearance of the surface because of the different focus position. This COC constant is used in the software to determine the best position for the next figuring step, or, in the case of a finished mirror, the best position for final focus. This subject brings us to a very important point to understand.

There is no fixed place as far as a specific number from which we need to start or finish. What the measurement process is about is the relationship *from one zone to the next*. That is all that matters, the shift in radius between the zones. The number on the micrometer that you start or finish with is of no concern, but rather the distance between each zone is what we consider. You can apply one number equally to all the zones to zero out the center, or change that number to zero out the edge, or to move to whatever position you wish to look at the mirror. That number is the COC constant, and that is how we use it. All the software programs have this adjustment, and the spreadsheet will have it too. It will be used extensively in deciding figuring sessions. I now fully see why fast mirrors are SO much more difficult!!! Indeed. Thanks Preston CZ

I think I understand what you're asking, in which case the answer is yes. There are two areas that correction action is noticed. One is nearer to the center, where the lap crosses the center before it spreads the work out because of the rotation of the table. After time, if left in one spot, you will see a zone develop somewhere inside the outer edge of the lap where it crosses center. And yes, it may approximate the 80% zone of the lap, although I have not measured it precisely. That is why you want to change your offsets regularly, as I've indicated in a previous posting.

The other place is of course at the end of the stroke, at about the 80% zone of the lap. Given its curvature and the nature of a straight across stroke (or more properly, an arc), that is where the majority of the outer correction is noticed. There are two ways to alleviate the inner zoning. One is to change offset, and the other is to change lap sizes. Remember I said that offsetting a lap causes it to act as a larger lap. CZ

Carl, A question arises from the previous dialog...Given your general description of the majority of work at the 80% radius of the lap, if one were to not move often enough, would one not perhaps see some zoning on the interior...i.e. about the 1.5" radius??? Thus the end at the outer end is the beginning at the inner zone and a slight digging may occur...I think that I may have seen this before visiting you...and perhaps after, until I realized what I think was happening. Regards, Preston Given all that, performing roughly a back and forth stroke across the mirror when the lap is approximately 60% the diameter of the area you're working, the lap will deposit the majority of the correction at 80% radius of the lap where it is positioned at the end of the stroke.

I like your spirit, John. I have a philosophy about this, and I'm experimenting to see if it works. What I think may be true in this illusion of a universe that we exist in with mirrors everywhere (pun intended) is that whatever we want in our lives we have to give away. Well, someday I want to become a really great mirror maker. Maybe if I help others attain their wishes with respect to mirror making, my wish will come true. CZ

Most things worth doing are. The more we learn together, the better! You don't have to do this; in fact, it would be to your competitive advantage to refrain from doing so. Your generosity truly astounds me sir. Thanks! John

Robert, No, wrong direction. -You want to make a LARGER lap. The reason the correction is falling into the inner zones is the lap is too small to get the correction any further out. Now understand, you can change that by using offset with the lap you have. You can use a LOT of offset as needed, as long as your overhang doesn't exceed 25% the diameter of the lap. A general rule of thumb for correcting a particular zone with a center over center stroke (and some marginal offset added in to prevent zoning) is 60% of the diameter you're working with. So given that rule, a 12.5" mirror would require a 7.5" diameter lap to correct the edge zone with a standard stroke. If you use a smaller lap, and you can, you have to use offset to compensate. Generally we rough in the parabola on a 12.5" mirror with a 7.25" lap, maybe followed by a 6-3/4" once the edge zone is coming along nicely. Between those two laps we can generally fully correct the outer two zones.

Okay, mirror makers, here's a general standard, for those making mirrors on machine with mirror face up and tool on top, using sub-diameter laps. When doing a full-length stroke, the way to get your correction further out is to use either more offset, or a larger lap. That is all there is. If your edge isn't correcting and you're doing a full-length stroke, either your offset is too narrow or you lap is too small, or a combination of both. There is much more to the story with regard to focal ratio and such, but it gets more complicated. Right now we need to understand the general rule of thumb, as stated above. CZ

Carl, Thank you for the starting point. I am now starting to understand what is going on. I appreciate you pointing me in the right direction. I tried an hour with the star lap and found it didn’t do much. So I remade it and did another hour. Last night I ended up seeming to correct from the center, which was not what I was expecting. Fortunately it did not do so badly. Looks like I have zones 2 and 3 very good, but the edge zones 4 and 5 look under corrected with they both seem to null at the same point. My next attempt will be to make a smaller lap and try to get the correction to work over the outer zones. Robert

Welcome, Stuart. Great to have you aboard! I'm getting ready to upload a small spreadsheet; we'll see how it goes. CZ Hello to all! I have just joined this group with the intent to learn more about the science and art of reflective optics. I feel like I have stumbled into an active gold mine, with successful, friendly miners offering me nuggets. I shall be eagerly following this project, learning, and contributing if there is something I can offer. I've used spreadsheets, but I'm hardly an experienced programmer. Cheers, Stuart Hutchins

First ML Spreadsheet

Since Tom is away I decided to put something together, or rather modify. I discovered a simple M-L spreadsheet that we created a few years back for the Optics Workshop in Bellingham WA. I decided to modify it and get it ready for an example piece, to build on

for the future. This gave me a chance to begin to get familiar with Excel again and its capabilities (the majority I will never use). The spreadsheet can be found in the files section in the Mirror Maker's Spreadsheet folder. It is titled "ML5zone.xls". This particular spreadsheet is for five zones. It can be used with any mirror of any focal ratio where a test of five zones is appropriate. I may ask Tom when he returns if he (or others) would like to build copies with other numbers of zones. The group can also decide later on whether they want to build on this one, and use those five or six spreadsheets for the base copies. I think you will find this module enjoyable to use. I made it as user-friendly as I could, with only the stuff you use in plain sight. The rest is hidden behind the graph. One interesting thing I noticed on upload was that Internet Explorer seems to open the spreadsheet up directly, for use in the browser window, which it appears to do fine. It can still be saved to your hard drive to be worked on, or added to, or modified, etc. I didn't spend a great deal of time on this, probably less than eight hours. I did run six different mirrors through it and found agreement with our docs, but even still, please consider this a beta version for a reasonable period of time. Comments are encouraged; let's get some discussion going. I'm hoping this is a worthy start to what we intend to launch in the near future. CZ

Mirror Makers Spreadsheet (instructions)

This post is the start of instruction specific to the spreadsheet (for those cataloguing the postings). I have some notes and a caution with respect to interpreting the ML graph and figuring. First let me caution for any who have missed this before. *The M-L graphical plot is NOT a graph of the surface of the mirror*. It is, rather, a representation of relative correction from zone to zone. When the progression goes upward with respect to the parabola from left to right between two zones, that space is *overcorrected*. When the progression goes downward from left to right between two zones that area is *under corrected*. That is key information that the ML graph shows to the mirror maker. Now, can an advanced mirror maker figure off of the ML graph? Yes, but I do suggest leaving that to the advanced mirror maker who has some experience using it, because at the 70% zone the surface of the mirror reverses from the ML plots. So we have to get the surface out of our mind when looking at this graph. There are other tools that will be used in conjunction with the graph, which will be covered over time, that tells us specifically about the mirror's surface.

So what are we looking for when we observe the graph? We look for a smooth progression, rather than choppy, erratic zones. This graph is extremely sensitive to slope error, and shows the slightest error very easily, especially the parabola-removed graph that we're using on the spreadsheet. Now we have something specific for those who are working at getting correction in the edge of mirrors right now.

On the spreadsheet you will see a column titled "percentage correction". -Very useful column as we have realized over the years. That is where we at ZOC begin. We don't look at the wavefront graph early on because we already know there is a mountain of glass to remove. What we look at is the percentage correction, specifically in the outer zones, and the ML progression. KEY POINT: What we attempt to do at the start of

figuring while we're correcting the outer zones of the mirror (which we do first) is keep the outer zones within 10% to 15% of each other. It doesn't always work that way with large fast mirrors, but that is what we strive for. On smaller, longer focus mirrors it is much easier. The very best would be to have all the zones correct evenly, equally, until the mirror is done. That rarely happens.

But here is the rule of thumb- the closer you have your outer zones correcting to each other in percentages, the smoother your mirror is, and the better it will go. Example plot, reading from the outside-in for a 10" F/6: edge zone-90%, next zone in- 82%, next zone in- 70% then to the center zone- 50%. As an example, that's a nice, smooth progression, and shows control in the work due to good technique and good choice of lap sizes. That is what the graph does for us. It helps the mirror maker who is striving for something more than average to control the smoothness of the surface. It is a very powerful tool for that purpose. So plug in those percentages mentioned above, and see what the resultant graph looks like. Then you know the "look" you're striving for while bringing in the rough parabola. There will be more on that subject later, when discussion begins happening (in the other direction). We still need feedback for numbers of zones that you're working on, or whether you don't like the concept of multiple spreadsheets, one for each zone and if you think it should be done otherwise. I've heard nothing yet on that subject. I'll probably not be offering any more until discussion specific to the subject gets moving. Don't be afraid to speak up and tell us what you think. The worst I can do is virtually bite your head off :) Oh, and students, perhaps now you realize why we started with what we did, the ML progression module. It is simply because, that is where we begin. CZ

Your method is still used by a well-known professional, today. As far as I know, Swayze Optical does do a lot of figuring with mirror on top of a large diameter tool, changing offset to control correction. It may be antique, but it is still viable. I dare say a lot of what we do here is also considered antique. So, what :) I would enjoy seeing your machine. If I lived close by I would stop by for a visit. I think you should start that 10" mirror...yes, just for fun. Carl

Carl: Gee with all the new things to use and know I feel kind of an antique. I did my mirrors on a homemade machine that resembled what the ATM book 1 on page 160 entitled "Lee's Machine". My machine was similar except I used plywood ratchets and the main arm instead of being pivoted was extended across my garage workshop to a moveable guide in an attempt to get as much a straight line motion as I could. The far end rode in a notched board that could be moved to different places for C over C to offset depending on which notch I selected. With full size tool and mirror and full sized laps and mainly with mirror on top I was able to polish and figure by changing the offset of the long arm with a little clean up by hand. I kept moving things around in an effort to avoid zones, which I figured would be the major problem with any machine work. I thought the main problem with machine polishing would be the regular motion a machine makes vs. the unintended variations in hand work. Some day I may do some re-grinding on my 8 inch as there are a couple of scratches where my wife tried to help me out and cleaned up my shop one day while I was at work and a couple of boulders got on the lap (although it was covered) during my absence. Wow, you sure can hear those dust

particles when they get on a well-pressed lap. Two strokes and I knew disaster had struck! I always started and ended a grinding or polishing session with handwork to get the "feel" of the lap or tool before engaging the machine. If I lived some place where I had a good site for mirror grinding would like to make up a 10 inch just for fun.

For the 12.5" at F/4.5 seven zones is a good number. For the 14.5" at F/5 seven is also good, maybe as few as six, but seven may do better if you can see the surface clearly enough. For the 17.5" at F/4.5 I would consider nine. CZ

We are working on a 12.5" f4.5 with 9 zones...that I would happily drop down to 5 or 6 on your recommendation... A 14.5" f 5 and a 17.5" f 4.5 that are only polished spherically...we are open to numbers of opening in the mask... Monday I will reread you last several post, and respond some more...did one figuring session today that must be measured tomorrow to see if it did what I was thinking... Best Regards, Preston

Number of Zones

The downside of extra zones at a magnification of one (naked eye) is a predominance of diffraction around the zone edges interfering with the ability to see the zone surface more readily. And then, too, they can be just too small to see well. On the other end, when using too few, the amount of slope within the zone becomes a problem. What happens is the shading is too strong from one side to the other, and matching the zones gets more difficult. For those who (successfully) use magnification by whatever means, the diffraction effect is greatly reduced, and any larger number of zones is workable. In general, there is nothing wrong with using an additional zone, so long as you have a sharp eye and feel that you can get a good set of readings. On the spreadsheet design, I would say we do indeed have enough horsepower to put together one all-encompassing document, however no large amount of it exists here, so I'm unable to visualize how it will be done, myself. It will necessarily get very complicated, because of the graphs, and because not all the computations that we will be doing are same from start to finish in the zone progression as in what you see in module #1. Some are much more complex. I note that programs that can do everything are written in programming language and have subroutines in them. Note also that each of such programs has a separate screen for a different function. You input the data, then they do the calculations and you choose the module you wish to use. But they are separate, and function one at a time on the screen.

Spreadsheets work a bit different. That is my argument from this viewpoint, but that view is limited. I'm looking for good argument in either direction on that issue, because such programming is out of our league, here. We found it quite workable to use six different documents, one for each number of zones from four through nine. I note here that the documents when finished are going to be relatively complex. I would say that the module just put up might be 20% of what we'll have when finished. I'm sure we'll be discussing this with Tom Karpf as we go along. Also there are several people that have indicated some ability with Excel and said they want to participate. Anyone care to weigh in? CZ

Hello, I usually use at least one more zone than is typically recommended. I would like to

understand the downside of extra zones except for extra testing time. So I use 7 zones for a 10-inch f5.5 and am planning on 9 for a 14 f5. I don't think one spreadsheet for each number of zones is a bad thing, but I bet we have enough spreadsheet and programming horsepower in the group to do a single one for all cases nicely in the end. Cheers, Eric we still need feedback for numbers of zones that you're working on, or whether you don't like the concept of multiple spreadsheets, one for each zone and if you think it should be done otherwise. I've heard nothing yet on that subject.

Carl, I have a question about the interpretation of Figure 4 in "Stalking the Wild Paraboloid". The comments in the text and on the figure regarding a low 70% zone and a high 50% zone appear to be interpreting the M-L plot as a surface plot. I think he is inferring a surface from the information he sees; at least I hope that is what he's doing. The original knife-edge data is not given for this plot, but it seems like the 50% zone and the 70% zone must be inflection points in the surface curve, not the peak and valley, as the comments suggest. That is true, they are indeed inflection points, but they can give information about the surface to those who know how to interpret it. (We're not there, just yet) I haven't yet tried "reverse engineering" the original knife-test data to see what the surface plot looks like, but it seems to me that the lowest valley must be to the right of the 50% zone, and that the highest peak must be to the right of the 70% zone.

The problem with this is where we place the focus. Your statement above is true at one focus, which is the lower position (position one). In the second position it is not true. What he has done in his strategy is the same thing we do here. He has an ***overcorrected*** outer zone, and ***under corrected*** from about the 50% to the 70% zone. He moved the plots to get that within tolerance for best fit on outer portion of the mirror, which at the same time raised the center. He simplified the job by adjusting focus to where the figuring job was the easiest to accomplish. It is a good question you raise. We will get into this stuff in great detail later on, when we have a wavefront and surface profile to observe. Then we will be able to compare the two, see the relationships between them, and get into specific figuring strategies.

By the way, have you considered using Suiter's "Testing Paraboloidal Mirrors" from TM#32? Although it's much more involved than "Stalking the Wild Paraboloid", I think the extra detail may be useful in discussing the development of the spreadsheet. Well, funny you ask. I just got through corresponding with Dick Suiter asking his permission to use the article on the mirror group. We intend to do precisely that. Thanks, Steve! Carl M-L NOT a surface profile (was: stalking the wild paraboloid)

It makes me feel better to know you're still here, Bratislav. I know you will keep us on the "straight and narrow" as the term puts it. I say that with humor, but at the same time am not joking. Somehow, knowing that you oversee this work is comforting. You can't say it too many times, and thank you for saying it yet again. This reminds me of something that I meant to point out but have not, as yet.

ML Plot is POINTS

The graph on the spreadsheet module that we uploaded- notice the knifedge plots on the ML graph...THEY ARE NOT CONNECTED BY A LINE. That is not a coincidence; there is a reason for that. It is a subtle reminder that they are knifedge plots, and is not to be thought of as a surface profile. Thanks again. (Preston, I'll get to your question soon, I need to spend some time on that one) CZ

This is my #1 argument against M-L. In fact, I myself have repeated here at least FOUR TIMES the fact that M-L graph is NOT representing surface errors, and that this is the most common mistake from people using it as figuring guidance. Yet we have had case of people IN THIS FORUM still being confused. What chance has an average, not so optically versed ATM reading the original article from S&T or any of the interpretations in various subsequent books? I am following the developments here with great interest. Not every day you get to peek into Zambuto's figuring logbooks, even indirectly. Can't wait for the next issue, to see the figuring steps and correction suggestions plugged into the spreadsheet. Bratislav

Gentlemen, There will be a surface profile, I assure you. We are building a mirror maker's spreadsheet. CZ

Bratislav, down the road, I think it would be interesting to see if Excel can be coaxed into generating a surface plot. I know this is beyond the immediate scope of the project, but it would be instructive to demonstrate how this is done, and it provides a different perspective on knife-test data. Steve, of course it can. In fact it is really easy to get surface data from K-E readings - you only need to plug in formulae from Texereau's spreadsheet into Excel. Some years ago I've done exactly that, and Excel has some nifty curve fitting "wizards" to produce nice, colorful curves. But I see no point in spending time doing this when Figure, Sixtests and Foucault all do exactly that, making it look much better and adding lots of other capabilities in the process. If you have educational value in mind, it makes sense of course, but again Texereau has done really fine job explaining it in "How to make a Telescope". I realize that adding a surface plot to the spreadsheet will not really compete with the programs that do this well. I was thinking along the lines of Mike Peck's modal algorithm, rather than Texereau's. It's possible that it will be too clunky in Excel, but I think it would be fun to try. -- Steve Koehler steve_koehler@s...

Preston asked: In general then, the lap is going center over center with a small amount of offset, being moved to prevent zoning with a series of smaller laps progressing toward the final work in the center. More offset acts as a larger lap allowing one to smooth the areas between 2 different lap sizes with the most work generally occurring at the 80% zone if your not offset and the other criteria that you listed. In general, yes. What is the general lap offset from the center when things are progressing normally, i.e. are we talking generally being within 1.00-1.50" of center. The typical range when all is progressing smoothly for appropriately sized laps will be 1/4" offset to 1.5" offset. When you have a zone, then more exotic technique (generally more offset) needs to be applied. I ask this because I have been chasing a raised area at the 50% area and have been working with both a 6" lap first and then a 5" working so that the 80% area was touching

or just passing the area that needed work, but my offsets had been more like 1.50-2.25" from the center. Stroke was used to keep the lap working the area intended. I think I've been going about this the hard way.

Yes. What I don't know is the total surface profile at this point. As far as the spreadsheet goes, it is behind for what we need to do here. That is fine, we'll do what we can. If your outer zones are well under corrected I would again use a full 60% diameter lap (7.5" in the case of a 12.5" mirror) and do a standard set of full length strokes with offset not exceeding 3/4" or 1", and the whole mirror will smooth out beautifully. The lumps will all disappear and the ML curve will have a perfect arc to it. But that can only be done to the point where the outer zone is fully corrected. After that, you have to use offset to chase an under corrected zone that needs to be pushed out, against a next zone outside of it that is fully corrected. If you need to push correction outward to a particular zone without correcting the next zone outside of it, you have to use extreme offset.

Here's what you do: Be certain to keep your 80% radius in the indicated place, and begin offsetting the lap in increments from your more extreme positions you have already been using, such as 1-3/4, 2", 2-1/4" and continue going outward from there. Use the same amount of time in each position, such as one minute or two minutes, and move out 1/4" or 1/8" at a time. But here is the key- you have to constrain your stroke length relative to the mirror diameter. That is, each time you offset the next step, your lap will be further out with respect to mirror diameter (assuming a standard arc on an A-arm machine). You have to also reset your stroke length in each position, so the lap does not correct further out.

And as you go outward beyond the standard offset range (1/4" to 1.5") it is advisable to keep your 80% place on the lap an additional 1/8" to as much as 1/4" further in on the glass from the place on the mirror you wish to "place" the correction. Now here's what happens. Somewhere in the extreme offset area, where your stroke as a result of large offset and shortening the stroke length becomes very short on the eccentric arm, you will notice that the correction begins to shift from the zone it is in to the intended position, the zone just out side of it. And if you keep your stroke length constrained to 1/8" or so inside of the intended point when using the extreme offset, you will see that that correction does not go into the next zone. Use the extreme positions as much as necessary until you get the desired ratio of correction between the two zones you're working on.

For those of you whose eyes have just now glazed-over, what I've given to Preston is a technique designed here in the last 1-2 years (it is of course based on experience from the previous five). This technique provides the capability to iron out a zonal kink. It is incredibly powerful and effective once mastered, and is what has enabled us in large part to make those "ruler-flat" mirrors that Bratislav has referred to. I do realize that it is tough to understand right now, as the group as a whole does not have the all the needed parameters at their disposal. Once the spreadsheet has enough information in it we will be going over this stuff in detail with graphs involved. It will all become much more clear. But don't forget this posting. CZ

Rich, The formula is I7, not seventeen. I7 *is* the user input field. Perhaps the label "RTA" is confusing. We could add "COC" in parenthesis if it would help. If you leave the chart where it is, the user fields are all left in the open. The mechanics are under the chart and are not necessary except for those who want to look under the hood to make modifications. Carl

Carl, Why do you add 17*0.0001 to your chosen COC constant? Is this field intended to provide an arbitrary offset from "centered"? If so, should a user input field be added?

Carl, I took a look at Spreadsheet 1.0.1 and have a few comments and a suggestion on handling a variable number of zones.
1. I think data input would be a tad cleaner if the fixed and moving source columns were combined, and the type of tester was entered in a separate cell. This would make the input area more compact, and make it easier (in the formulas) to understand how fixed and moving source are handled differently.
2. (A minor nit) The B19:B23 area in the RTA calculation is redundant. For example, E12 and D12 are additive inverses of each other, so A19 and A20 will always have the same value. On the subject of handling a variable number of zones, I highly recommend doing this. From a software engineering perspective, maintaining multiple copies of only slightly different data leads to consistency errors when updates are made.

If we want to evolve the spreadsheet to do more over time, tackling the variable number of zones problem should be done early. I suspect that if it is done well, it will not make the spreadsheet harder to use or to read. From my VERY limited knowledge of spreadsheets, I think putting all the zone-dependent data at the bottom could do it, so that more rows can be added, as needed. I'm sure Excel savvy programmers are very adept at this. Down the road, I think it would be interesting to see if Excel can be coaxed into generating a surface plot. I know this is beyond the immediate scope of the project, but it would be instructive to demonstrate how this is done, and it provides a different perspective on knife-test data. -- Steve Koehler

There's nothing wrong with that, unless you're a production shop trying to make a living. Even then, it’s not far off the mark. Notice how much energy is takes to do that... Your accuracy sounds very good. It will serve you well if that is indeed the case. CZ

By the way, with 9 zones ...it takes me almost 1 hour to collect 2 data sets, but each set is typically within .001-.002" within one another.

James, I think you've found your "calling". At first glance, the implementation is very slick. -I had to laugh when I read where you refer people to the z-mirror group. CZ I've incorporated Carl's recent M-L spreadsheet math into FigureXP. I think I got everything working correctly. Here's a screen shot showing the implementation: http://lerch.no-ip.com/atm/ZOC10inch_M-L_Plot.gif the data came from Carl's 10" data sheet in the files section.

Pitch and Crushed Walnut Shells

You know, Tom, Bob Goff *did* use walnut shells, from my vague recollection as well, however I don't believe he was quoted in this forum on the subject. Personally, I can't answer your questions on that issue, both because I'm terribly preoccupied on several fronts, but also because I have little expertise on the subject. I believe the walnut shells were to help in the properties of the flat polisher, a very large steel table with pitch on it. I would guess that one did not want it to flow so rapidly, and yet have the properties of medium Gugolz pitch. -That's just a guess. When it comes to mirror making, standard pitch of standard values can go a long way toward making very fine product. CZ

I've done some digging in the archives here, and I can't find mention of something I vaguely remember Bob Goff mentioning: Use soft pitch and add crushed walnut shells to stiffen it. Can anyone elaborate on this? How is soft pitch and walnut shells different from pitch made harder by adding rosin, or boiling off volatile substances, etc.? Does this imply that viscosity of pitch is different at different 'scale lengths?' Does soft pitch have good viscosity qualities on a short scale length, but bad viscosity qualities on a long scale length? Does adding walnut shells help the viscosity qualities on a long scale length? Finally, how can we measure these various long and short scale length viscosities? (I think I know how to measure the short scale length stuff...use a Twyman viscosity tester.) Thanks in advance. Tom Krajci Albuquerque, New Mexico (Settling back in the US)

Polarizer Stress Test - Quarter Wave Plate

I'll give you my two cents because we do a lot of stress testing. And it is only two cents, mind you. One, if you can get a mirror to appear perfectly uniform using only two polarizers, you're doing well. Two, you may be creating little more than frustration by adding more aspects to make the test more critical, Mirrors that show no strain whatsoever in the cross-polarization test are very well annealed from our experience, and are in truth probably not in the majority. Smaller mirrors tend to have better anneal overall. Larger ones require some educated compromise in some instances. We made a lot of very good mirrors before we ever started strain testing, and many had less then perfect anneal. They still work well. All the "blue ashtrays" had significant strain in them, but they still perform well. If you get a superb anneal, consider yourself fortunate, what it will mainly do for you is cause the glass to remain more stable during the fabrication process, making your testing more uniform and predictable. CZ

I have read something in Maksutov's second book (Fabrication and Testing of Astronomical Optics) about stress testing that's a bit different from the way I've heard from many English speaking ATM's. Maksutov says you use two polarizers, but you also have a quarter wave plate in the optical patch. (The quarter wave plate is not mentioned in most ATM posts I read.) Maksutov (if I translate him correctly) says the quarter wave plate helps to measure the stress induced polarization, and not other forms, or random polarization. Does anyone out there use quarter wave plates as part of their stress testing setup? The Melles Griot URL below mentions use of a "tint plate" (a full wave plate) for

photo elastic stress analysis. From a physics standpoint, what is the best approach to stress test mirror blanks? Should I use just two polarizers or two polarizers and a quarter wave plate? Other? See: http://www.garnerglass.com/Stress/
http://www.engr.iupui.edu/me/courses/me272lab/exp6.pdf
http://www.mellesgriot.com/pdf/0012.23-12.24.pdf Thanks in advance. Tom Krajci
Albuquerque, New Mexico

Mask Zones and Spreadsheet Design

I wish to reply to John and Steve's suggestions. I think they're all good. So, where are you, spreadsheet wizards? There are several of you who have indicated you want to be involved, so do take the spreadsheet and continue developing it. What you can do is, after you have created a change, make a comments cell for the revisions, label it a new version, and upload it. For this first M-L module perhaps we could keep it version 1-x-x. If you change some functions, change it to 1.1-x, and 1.2-x, and so on. I've gotten pretty busy with several things I have on hand, so I don't know precisely when I'll get to the second module. The intention is to work on it this next weekend. What I plan to do is build the wavefront profile and integrate it. That gives us a surface to work with, in combination with ML. With that, we can teach how to read this thing and do something with it. I'm very interested to see if the spreadsheet people can actually have the whole document change zone numbers, and successfully change the graphs with it, and etc. The wavefront profile will be the most complicated module, I think, as one condition is built upon another, then there are separate calculations at the end. Tom Karpf returns Wed. We'll have to give him some time to catch up, but don't let that prevent anyone who wants to, to play with the current version and modify it. It’s your spreadsheet; I'm just supplying the raw, basic functions. CZ

Good day Everyone, A fascinating topic this one. I've toyed with the sheet and have 2 comments to make. Since this is a users tool it should include the ability to switch between Metric and Imperial measurements. The zone radius otherwise makes no sense. Not all users will be using imperial. One other thing, which I think has been mentioned already, is that it really should be setup to be capable of inputting the number of zones that are required. This really does make it easier down the track when adding or modifying 5,6,7,8,9,10 etc. etc. zone sheets. A cell where you can input the number of zones to test or better yet, a drop down list box to select the number of zones (thereby preventing typos ending up in the sheet.) Cheers John Murray

Carl, I took a look at Spreadsheet 1.0.1 and have a few comments and a suggestion on handling a variable number of zones.
1. I think data input would be a tad cleaner if the fixed and moving source columns were combined, and the type of tester was entered in a separate cell. This would make the input area more compact, and make it easier (in the formulas) to understand how fixed and moving source are handled differently.
2. (Minor nit) The B19:B23 area in the RTA calculation is redundant. For example, E12 and D12 are additive inverses of each other, so A19 and A20 will always have the same value. On the subject of handling a variable number of zones, I highly recommend doing

this. From a software engineering perspective, maintaining multiple copies of only slightly different data leads to consistency errors when updates are made. If we want to evolve the spreadsheet to do more over time, tackling the variable number of zones problem should be done early. I suspect that if it is done well, it will not make the spreadsheet harder to use or to read. From my VERY limited knowledge of spreadsheets, I think putting all the zone-dependent data at the bottom could do it, so that more rows can be added, as needed. I'm sure Excel savvy programmers are very adept at this. -- Steve Koehler

John, If I may ask, please put your name on the file in the description line so we know who is doing what and can begin to keep it straight. (I have separated the docs we put up in a folder, as those have the original modules we will be using in the instruction.) I expect there will be many working on the project with different documents. How this will all be organized and focused into one document we don't yet know :)

BTW I used Excel '97 as well. I understand it may be the most compatible version of the program that is still used today, so that the most folks can operate it. Thanks, CZ

Good day Again, To get an idea of what I am doing for the multi zone version, I have uploaded the very rough draft of the spreadsheet called MLMultiZoneVer1.0.0.xls to the yahoo groups folder we are using. Currently the changes are minor.
1) The graph is put onto another sheet and is currently inoperable. This will be fixed. In future it would be a good idea to have separate sheets for each graph type that will be generated.
2) Lots of #ref in the cells. This is due to the fact that I'm using vba to insert the correct number of cells into the NEW sheet called MultiZoneVersion. These errors will be addressed shortly.
3) The sheet is still protected bar the data entry areas. This changes obviously according to how many zones are selected.
4) Cell H6 (yellow) is for entry of the desired number of zones. Enter the number and then press the button to create the data areas.
5) The sheet itself was renamed to MLMultiZoneVer1.0.0.xls instead of ML5zonev.1.0.1.xls, as the sheet is no longer for a 5-zone setup.
6) The vba is accessible and easy to understand hopefully. I'm having to put my excel cap back on after not doing some for a year or so. Currently the sheet is not functioning for data reduction as I am still working on the zone radius calculations. Once that is sorted I'll post a revision to the group folder. I hope these changes are ok. Cheers John ps. All work is being done with excel97. An oldie but a goodie.

The tendency of technology is to complicate things. One major reason for our success here at ZOC is we only complicate what is necessary to complicate. We only use the amount of technology that is absolutely necessary to get the job done. Programs that have a lot of features and "wiz-bang" necessarily get complicated. A first hint at one aspect of where this wants to be taken has incorporated multiple sheets and macros. I think there's nothing wrong with that, at the same time I'm going to provide some suggested guidelines. Most of you may be familiar with our (former) documentation. For those of

you who don't know this that printed document IS the working spreadsheet. That one page has all the graphs, all the input data, the averaged zone measurements, the knifedge deviation, the data reduction, everything. It is all on one 8.5" by 11" sheet. (The formulas are obviously spread out over the spreadsheet out of the picture of the printed page.) So why is it that way? It is because it is highly functional. Every input we use when analyzing a mirror, that resides inside and outside of that printed page will fit on a 20" monitor. We can input any number of the test data from any zone and watch all three graphs, the data reduction, the zone percentages, etc., all at one glance. I have uploaded to the spreadsheet file a sample screenshot (See the ZOC folder in the spreadsheet folder). Let's see if there are programmers out there can make the package as functional and usable as it is feature-laden.

What you see on that page is what we see and look at when we do the work. Outside of exotic techniques we do from time to time, it is all there. Take a good look; no one who has not visited this shop has ever seen this. You'll notice four axes of measurements. On the lower right we have two floating palettes that we can drag around the screen. One is a mini spreadsheet that contains working information as titled (outlined in violet). The other is the history of all the measurements on that mirror. There are also astigmatism tools in that screenshot, where we can see astigmatism information show up on all three graphs. Here is the main point of function on that screen- we can type in any parameter or any measurement change, and see immediately how it affects everything. -Absolutely everything. That allows us to make a decision easily and straightforward. Please also keep in mind that only about 20-25% of the total data and functionality has been uploaded yet. The full version, (even with one set of zones) is still a long way off. The reason I'm saying all this is I don't want us to lose sight of the goal, and that is creating a tool for making mirrors. The finished mirror is the goal- a word to the wise. CZ

John (and group) I came to the same conclusion as you, probably in the same time frame. Thank you for your thoughtful letter. I stayed up late last night because I couldn't sleep, and took a fresh look at a rather old, and many times added-onto spreadsheet. What I decided to do was forget the previous formatting (mainly for the printed page) and go through the entire thing and clean it up. Although not finished, it’s cleaning up nicely. It’s not terribly complex, in it purest form. I have an important point to note here, and then I'll get on with the plan. First, I want to mention that the stand-alone ML graph was an afterthought. I threw it up there because I had an iteration of ML alone, by itself. It was quick and easy.

However I note that it is not built after the same fashion as our spreadsheet. It has a different core. Our spreadsheet is built on the Genmir code from Telescope Making Magazine #32. It is the Exploratory Method of Focus, written by Dick Suiter. It builds the whole base different, so the two are not really compatible. What I'm saying is, after looking at the code for each spreadsheet, it won' be viable for me to build anything further onto the ML graph. Folks can have it, as it is, modify it as they wish, but that's it for that one. Now, what I plan to do- in my mind previously, the project looked very big. I have not done any serious spreadsheet rebuilding or formatting for years, now. I was out of practice. But after tearing one apart and cleaning out all the redundancies, (both for

printing and otherwise), the spreadsheet has gotten significantly more simple. I can now see my way clear to getting a copy done in Excel and getting the whole thing up in one piece. So I'm going to do precisely that. If the group can be patient with me, I'll take probably a seven-zone and go completely through it and produce a finished copy of a fully functional document, with all three graphs. You made a point about the visible page and our needs vs. individual needs. The purpose of having this spreadsheet at all, as opposed to other programs out there, is to be able to put all applicable, user-necessary information and tools on screen simultaneously. There is no program in existence that does what this thing can do for the mirror maker who uses a knifedge. I'm not saying they can't get there one way or another, but this thing is designed "for mirror makers, by a mirror maker". When I lay this thing out, although it won't be highly polished, the necessary tools will be in one place with the graphs, closely approximating the resolution on an average monitor. I stress that it will be important to have these things if this spreadsheet will be used for instruction. This point will be understood much better, later on. So I'll do as indicated, and then turn it over to the group. At that point, you can do with it what you will. Thanks, John Carl PS I'm also thinking about scanning the entire TM #32 article (16 pages, I think) and getting it up for study purposes. Good day

Carl, You raise some valid points. Technology and how it is used by ordinary people with an interest in whatever grabs their attention is fascinating to watch in action... <snip I think this is a great learning exercise for everyone and appreciate the time that you are putting into this. As you say at the end of your message the goal is to create a tool for making mirrors. I agree, let's not lose sight of that..... ;-) Due to a couple days committed previously I hope to have the Couder zone stuff sorted and uploaded within a couple days hopefully. Cheers John Murray Whyalla South Australia

Thank you, Dick. Good stuff. I think we'll all go have a look. Spreadsheet people: I guess I had envisioned something similar as well, to have blank zones that remain in place as opposed to appearing out of nowhere, so the screen format doesn't get jostled around when a different number of zones are selected. CZ

I have written a couple of Excel spreadsheets for zonal testing. They are at: http://home.digitalexp.com/~suiterhr/TM/tex8inch.xls (as near as I can get to a reproduction of Texereau) http://www.willbell.com/tm/atmmanual/LeCleireFoucaultFinalB.xls (for the new book by the LeCleires). I have found that it is important to protect the cells that people have no business messing around with. Mark the cells they are allowed to change with a yellow background. If you have a 5-zone mask, plot over 12 zones, say, with the last 7 zones empty. Use auto-scaling on zonal radius, and it will plot only the populated zones. Most reduction procedure integrate from the center out, so empty zones won't mess the results up. Another feature that I've discarded in moving from hand- written mirror programs to Excel is the automatic Texereau "line-9" constant search. It’s easy to just fiddle with it by hand and watch the graphs change. Excel is a fast method of getting your algorithm up and running, but hand-written programs can do more and can isolate the fumble-fingered user from damaging the code. On the other hand, if you thoroughly understand everything in the worksheet, it is all to the good. People often use canned programs

having no idea of their weak regions or the approximations that went into them. HR Suiter

Ricardo, I think you're doing some nice work; I like some of the features you've incorporated. We have a folder in the files section, called the Mirror Maker's Spreadsheet. In it is a sub-folder for the spreadsheets themselves, and I'm suggesting that each contributor begin their own folder, so we know where to go for a particular individual's series of work. Carl

Hi, After thinking a lot, I think I found a balance between both approaches, as I don´t know where to put this thing, so it´s on my site http://www.geocities.com/rdunna.geo/mlcz.zip. I need some VBA help on how to update the chart when number of zones changes. Because there´s a lot of features and it´s small a new design may be necessary if things get complicated. Ricardo Dunna Spreadsheet people: I guess I had envisioned something similar as well, to have blank zones that remain in place as opposed to appearing out of nowhere, so the screen format doesn't get jostled around when a different number of zones are selected.

Hello, group. I worked fast and hard to get something together as soon as possible because I'm going to be otherwise preoccupied for a few weeks and won't have much time to participate in the project for a while. In the files section, find: Mirror Maker's Spreadsheet/The Spreadsheets/ZOC generated files/7zone ver.2.0.0.xls. The file is a full working version of the majority of the tools and all the graphs that we use in-house. Regrettably, it is only a seven-zone version, with "Imperial" measurements and set up for a fixed source tester. The intent of this document is to give the spreadsheet team (Tom, are you back yet?) the essential data to get this thing launched, to make the kind of document you all want to wind up with. The typical disclaimers apply- although I did run about five mirrors through it with good success. Consider it a beta version for a reasonable amount of time. I do have to say, our rather old version cleaned up quite well in this process. I found a lot of redundancy and was able to streamline it down to a much more palatable document. I'm available to answer questions from time to time, but will not be able to spend long hours in development in the near future. I think what we have here now is sufficient to get the ideas and information across, for the team to be able to go to work I look forward to comments. CZ

So far it appears our efforts have been on an individual basis (which is where things begin, I suppose). In my opinion it would also be beneficial for those who have volunteered to participate in the project to start talking to each other. Someone may need to designate themselves project head, and network (even in the background if that works) with all those who want to be involved. A quick look back over the last couple of week's worth of postings should show who those people are. I've taken this about as far as my expertise allows, as my spreadsheet capability is rather basic (I'm not talking about the programming language). A coordinated effort between the skill and talent here should be able to produce something rather extraordinary. I do appreciate those who are willing to participate. It’s in in your hands, now. On another subject, for those who are making mirrors, you're welcome to ask fabrication/technique questions. We're still early to have a

document that everyone can use as a common denominator, but in case it wasn't noticed, I did throw out a criteria and description for starting technique with our first ML graph that has not generated any discussion as yet. Perhaps it was too subtle. I guess we can go over it again when we have more tools. CZ

Spreadsheet

Bob, There are two very nice things about a spreadsheet.
1. The online group version need not remain static. It can always be revised.
2. It doesn't require a programmer to modify it for individual use. Anyone who wants to use it can move cells, revise charts for their specific versions and taste, and resize anything they wish. So don't despair, just because you can't work on it right now doesn't mean its going away. The uploaded version is public domain. It now belongs to everybody. CZ

This is just killing me!!! I have wanted to get into something like this for years and now that there is lots of activity on a really great site with lots of really smart people, my discretionary time is at a minimum. I have had a chance to glance at the first chart and it looks a lot like some of the output from "Admir", which is my software of choice right now but expect that the final version of this spreadsheet will be a real help to mirror fabricators who are just starting out and those that have lots of experience. I believe that you have headed this project in the right direction, Carl, thanks for stirring up the pot!! Got to go to work and try to keep Carl in the "hot seat" and stay ahead of the output of his shop. There are lots of mirror cells and prototypes to finish. See You, Bob

Submerged Polishing Question

Submerged polishing along with other techniques is a matter of priority. You won't find a company who has rough surfaces, or turned edges, or inaccurate figures using submerged polishing. Also, like so many other things, there is a tooling, labor, and cost factor involved. Who will pay for it? Then the decision of diminishing returns comes also into play. A company who is attempting the absolute state of the art would only use submerged polishing in our estimation. I would say it is the last item in a long list of things to do to achieve such. I'm certain it will interest you that we do indeed employ a very effective variation on submerged polishing. It has three aspects.
1. First is humidity. Imagine that the shop humidity is 100%. The mirror is wet, so there is no evaporation. Would that not be similar? We don't use 100% humidity, but we keep it a 70% and above, now. It is rather effective at keeping the surface very wet. By the time the lap covers the entire surface, very little drying occurs.
2. Second, is simply having the mirror face up. Bad mirrors are often referred to as "birdbaths" for obvious reasons. Well, you do have a bowl that holds water. The interesting thing is using the figuring technique we use; the final polishing (figuring) is done with much less or no overhang. We typically fill the bowl of the mirror with water in the final stages, which is essentially polishing under water.
3. Third is effective use of a sprayer. We use a spray bottle on the edges during final figuring when the lap isn't wetting the entire surface, and our final wipes are always

along the edges of a wet mirror with the lap.
4. Let's throw a fourth one in there. Being as the mirror is face up, the lap is continually wiping figuring solution off the surface, so it needs to be continually replenished. This is one of the techniques of submerged polishing, to keep fresh solution going to the surface continually. I propose that the combination of these techniques very closely approximates the full effect of submerged polish. So in a real sense, we essentially perform it. I mean, how do you think we get this contrast :) CZ

Hello Carl.... I was scanning the ATM archives the past few nights and came across the topic of "submerged polishing", with some brief remarks from different users, but not much detail. Have you ever used this technique? From all that has been discussed on this group, I can't recall any mention of this techniques having been, or currently being used at ZOC. If you have a moment, can you please discuss this technique and whatever pros and cons it has, and why ZOC (perhaps) is not using it? Thanks, Bob Mazzullo P.S. I am not planning on implementing this technique at so early a point in my work. From what I have read, it sounds very interesting and I am just curious, but there must be reasons why it isn't more widely used.

Machine Figuring

Robert, It appears you could use some basic parameters, such as in "big picture" stuff. I'm not able to answer the question you asked; there is not enough information for me. An aspheric does not appear all at once, especially fast ones. Any particular lap and stroke length is good for a particular region of radius, not the whole mirror. You have to tell me size and F/ratio, and what area of the mirror you wish to work on. It might be to your benefit to do some reading either on the Internet or in books, or both, about basic figuring technique. Understand that machines don't make mirrors, opticians do. You need to have some kind of understanding of how to figure a mirror before you turn on the machine. What we do with our machine figuring is precisely mimic handwork. It is exactly the same theory and technique. The only difference is the machine can precisely measure positioning, which I find helpful for the way we do things. Once you understand how to figure a mirror with sub diameter tools (on top), it is essentially a snap to convert the work to a machine. If you want to enhance your learning by asking specific questions here, you're welcome to do it and I'll do the best I can. I appreciate that you asked this one, however I don't have enough information to answer it. If you can be more specific about where you're at, I might have a shot a supplying some insight. Thank you for your suggestion on the spreadsheet project, and supplying some leadership. Carl

Carl, Thank you for the help so far that you have given. I had another question about machine figuring technique. You have talked about setting the offset of the tool to target the zones that need to be worked. How much stroke should I use on the eccentric? Does it always go completely across the mirror edge to edge? Robert

Carl, Ok that actually pointed me into the right direction. I looked up some info in books on sub diameter tools. This gives me an idea of what to do. Good, and good. As far as the TM spreadsheet I will be glad to do the work to compile the list of things to do for the

sheet. I can put them all together in the FA document. We can add to the list any fixes, must have features, and suggested add-ons. I was thinking if we had a list of tasks that it is easier to assign work to people who want to contribute. Robert So far the consensus of the group seems to be after three items. One is the ability to use different numbers of zones. If I had my personal choice, the number would be between four and ten (to keep it simple as possible). With a 10 zone we have enough to measure a 24-inch at F/4.1. In fact right now we're doing it with nine. The second item is a must-have, a one-cell directed conversion to millimeters that will hold consistent throughout the document. No small deal, unless one of our wizards knows a shortcut. And the third is the ability to input moving or fixed source data. That should be the easiest. One more that has not been discussed but I think is important is the ability to handle zone inputs differently. Some will use the Pinstick method and want to input radii directly. Some will want radius to be 50% of a zone opening, and some will want it at 70% (is 70% the other correct figure?). As far as I know that covers all the bases at this point. If those items could be accomplished with a layout and functionality of what we have to begin with, I think the document would be unprecedented. CZ

Peter, since you directed this query specifically to me, I'll answer it. I appreciate the suggestion, and I don't necessarily disagree. At the same time I'm unwilling to lay a "should" on a country that refused to convert to the metric system. That was already tried and it failed. John called the system "Imperial" measurement and to be quite frank I think it is appropriately titled. Politics aside, this spreadsheet will be "big" enough to meet the needs of mirror makers around the world, many of whom still use inches and micro inches. Heck, if we made the switch I would have to buy several new micrometers. I for one am going to be stubborn like the rest of the country. Carl The second item is a must-have, a one-cell directed conversion to millimeters that will hold consistent throughout the document. No small deal, unless one of our wizards knows a shortcut. Well Carl, I am no wizard but why not have all numbers and calculations in metric millimeters, most of the world does it and so should we. Peter DB

Machine Figuring and the Edge

James, I wish to thank you for addressing the edge condition specifically. It is a very important issue, obviously. Assuming the edge is reasonable from the beginning, the machine group is going to learn something very interesting over time, and so wonderful that it is hard to swallow, initially, for those who do not understand. This sounds hard to believe, but it is absolute fact.

The method that you are learning requires no specific attention to the edge (other than a minor caveat that is small detail for much later on). The strange and wonderful aspect of the method is that by its very nature, it repairs edges and brings them to a perfectly balanced diffraction ring, every time, all the time and without fail. How does the group think that 1,000 mirrors all have ***perfectly balanced diffraction rings***? Heck, we're not THAT good.

The answer is, the method by its very nature will remove a minor turned edge on a larger

fast mirror that has a lot of correcting to do, and it will balance that edge with a diffraction ring that is essentially indistinguishable from perfect. I suppose the next question is "how". Well, in short, the lap never goes beyond 25% overhang. When a lap goes across the edge at the prescribed overhang with the weight on it perfectly balanced (quill in the center) by its very nature it MUST repair and balance a turned edge given enough time. It will bring the outer zones of the mirror down to where the edge exists, if enough correction time is involved. Otherwise, if the edge is decent to begin with, the method will keep it balanced until your work is through.

James, you did touch on the caveat, and that would essentially be ***severely overcorrecting*** the edge. If that happens and the offset is very strong, the outer zone can indeed roll, but I don't need to go into that right now, because if students keep to the techniques within reason, that aspect is a pitfall they may rarely if ever, come across. Understand, everybody that this kind of information is in a large sense unique to the amateur community.

At least three commercial mirror makers that I know of have historically corrected the edge by running a lap around it by hand, hanging it off the edge and scrubbing as the mirror goes around. Hence, every mirror they made had a turned down edge. They were correcting from the 70% zone to the edge, by making that portion of the mirror a longer radius. Why? because its faster! They can finish a mirror much quicker than we do. This method was so entrenched that there are those who did not understand that it was actually possible to fabricate a mirror *without* a turned edge! I recall one European reseller of one of the TDE mirror makers defending the product by stating that Swayze and Zambuto "color" the edges of their mirrors, which is why they don't have TDE.

Well, I think some related parties have learned better by now, and perhaps have even learned how to do the job better as well. I'm pleased for that, and they have my best wishes. I have indeed noticed improvements in the industry recently and I think that's good for everyone. But I got off track... So, "machine people", watch the diffraction ring as you work, and behold the wonder of an edge that never goes astray.

Furthermore, you will find something else rather unique about the method. No matter what you do, if you follow the full body of the technique that we teach, everything that you do to the mirror when figuring will tend to make the surface look smoother, and better overall. Every time you touch a troubled mirror with your technique, the mirror will look better, and better, until such point as it appears as the ones you see from our photos. More on how and why later, as we go along over time. Thanks again for pointing to the edge situation and taking a stab at it. Your point was correct, James. Carl

And the secret ingredient (because you mentioned rolled edge in point 7 above)- I wonder if anyone has noticed that we have said nothing about how to handle the edge with this machine figuring, and how to prevent turning it? I'll say at this point that I won't address it because we don't have to. I'll leave it at that for now. I'll take a stab at this, as the 12.5" taught me how to make the edge bad, how to fix it, and how to avoid making bad again...
Re: Figuring lap preparations

Hello Carl, Thanks for this info it has been helpful, I do have several follow-up questions. Okay, let's talk about the lap. We like soft pitch. We use Gugolz #64 mixed with #55 for our figuring laps, perhaps 25% to 33% of the #55 in the mix. I have used soft pitch as well (25% Gugolz 55 and 75% Gugolz 64) at 72 degrees and have gotten very nice smooth surfaces. I have produced a rolled edge that is difficult to get rid of with this pitch when I polish to a sphere using a faster rotation and a stationary arm with a bit of wobble (per Dennis Rech's advice). I tried a harder pitch during polishing but I seemed to make zones then. Do you use a different hardness pitch for the initial polish than for the figuring?

Yes, we use straight Gugolz 64 for polish. Don't worry about zones. On a sphere they look MUCH worse than they are, and in fact are essentially meaningless during polish. What are important are two things:
1. A good figure of revolution.
2. A good edge.
Everything else is fixable. The first thing you will notice when parabolizing using good technique is all that "waffle" look will promptly disappear. If it is a rough sphere, that is all you need. Understand also that polish technique (not figuring, but polish), as far as positioning and stroke, etc., plays a role in how the edge comes out. We can talk about that later if need be. I have built a pitch tester from Texereau's book and have measured several different pitches at different temperatures with it; I can post the results if anyone is interested. The nice thing about Gugolz is, it is consistent. That's why professionals use it. Why is a hot press more likely to sleek than a cold press and what can done to minimize it? To answer the first part, we don't know. To answer the second, ***don't hot press on your mirror***. We amateurs (speaking for me) rarely have two mirrors at exactly (how exact does it need to be?) the same ROC to press on a different one than the one we are making. Yes, I know. The sleek thing is a condition that we noticed because we strive to deliver mirrors that are cosmetically flawless. We don't guarantee that, but we come damn close the majority of the time. When hot pressing, we noticed sleeks develop under the lap. So we either cold press for a longer period of time which does the same thing, or we use another glass. Understand this is a very small detail (we sweat the very small stuff, you know) and is relative to a pristine polish, which is indistinguishable from perfect in its cosmetic. So don't put too much concern on the issue at this time. If you notice sleeking worse than you're used to, then you're operating at a very high level, and can then remember this subject. I have also been brushing my laps to get the action right, they look like the small marks in your photo, I was surprised to see in the photo the very deep brush marks in the surface, maybe 3 per facet or are these the ones you are referring to? I had always thought one wanted large lightly brushed facets. What are these deep grooves for, or are they not as deep as they look in the photo...

Those are not brush marks; they are a ***second level of faceting***, done by one swipe of the razor blade. They are purposely ragged. They simply add more edges for cutting. Our laps have three levels of faceting- the main facets and the micro facets, both done with the razor blade, and the brush lines, done with a wire brush. 5. Cerium quality. We use premium grade cerium mixed down very thin for figuring. Our raw mix that we ball-mill

is 1/3 solids and 2/3 water. We take that raw mix after it is milled and mix that at one ounce of cerium to a gallon of water, so it is essentially 128 to one. Believe me it cuts just as fast as thick cerium. Does this produce a better compound than eluting the cerium? Or is it just a method to make a larger quantity? I've been pouring off the fine suspension from the top each time I mix a batch during the polishing phase and using it for figuring. Nothing wrong with that; the difference is we get to use ALL of our cerium, and that is only because we ball-mill it. Otherwise, we used to run it through coffee filters, at the 128:1 mix, and so we wasted a lot of material. We now use 100% of our compound, which is probably neither here-nor-there, but we do use the same stuff for finish polish, so we need a good amount of it. 7. And the secret ingredient (because you mentioned rolled edge)- I wonder if anyone has noticed that we have said nothing about how to handle the edge with this machine figuring, and how to prevent turning it? I'll say at this point that I won't address it because we don't have to. I'll leave it at that for now. We noticed... Cheers, Eric Cheers as well, Carl

Hi, Rich I have two polished 8" f/6 mirrors waiting figuring, each with a slight rolled edge. ... The mirrors were polished with a center over center stroke with about a 1" overhang (< 25%) on each side. Gugolz 64, 72 degrees, well pressed, hole in center. Since this seems to satisfy the conditions for no turned edge, yet I have one (small but there), I assume there are one or more things that are still not quite right.

Yes, the glass will always tell us whether we're doing what it needs. There is a caveat here from our experience, and that is, smaller mirrors are more difficult to polish without slight turned edge. Our 7's and 8's require some careful attention on this issue. First, I would not rely on figuring to remove a turned edge on an 8" F/6, as not enough correction goes on to fix any substantial problem. That is the department of larger, faster mirrors.

There are two ways to go about this that I can suggest, and there may be others as well, but I can give you two. In short, we found that by reducing our overhang to 20% we were able to flatten the edges on our 7" mirrors. Now Preston is right- we use a different method for polish than mimicking the barrel-stroke done by hand. We spin the mirror at high speed (by spinning the table) and place the lap over approx. the 50% to 70% zone, which spins the lap also at high speed, as a result. Then we move the eccentric slowly in and out from an overhang of 25% (or 20% for small mirrors) down to a minimal amount somewhere around 3/4 or an inch, depending on mirror size.

We never go across the mirror with the eccentric at all, the lap stays on one side. If you're going to be a machine worker, you might look at this technique. Most professionals and now many amateurs use this as well, given the trend of M-O-M machines going on. So you can look at that as one option.

The other option is, when all else fails go to hand work with a full diameter lap, mirror on top. That will raise the edge quickly and effectively. I suppose we should have a movie of polish technique as well. I may do that sometime soon if there is confusion surrounding the method.

Carl I don't want to proceed to figuring if there is a problem that needs rectifying. Does this sound like a problem or just par for the course? If you think I have a problem, do you have any advice on how to troubleshoot this? Is there a hit list of things to check? Can I reasonably expect the figuring process to fix this? I can provide a picture if it would be helpful. Thanks again for the wonderful advice you give to this group. PS. I wouldn't mind being another guinea pig (figuratively speaking) but, like Preston, I would need to verify my testing accuracy. These will be my first two "finished" mirrors and all of my equipment is newly made and unproven. Hey, maybe that's my problem.

Telescope Mirror Making Spreadsheets

Ricardo, I like your upload today, some very solid work. We will be teaching astigmatism analysis when there is a version done that everyone can use. Meanwhile if someone would like a specific aspect, we can show some conceptual application. I do think we have discussed it in the past, but don't recall the specific. The main form on the new 7 zones is clean the way I see it, all working formulas are off to the side, off screen. But if the group feels the need to put them somewhere else, I guess that can be done too. I've uploaded an updated version, 2.0.1. It has some comment revisions, a couple of labels changed, and a dead column of cells removed that was not in use. It was the "(2Rp/r)/2" routine, an old carryover from a time when I divided the ML graph also into 1/2 the tolerance. That could be confusing to someone who is trying to figure out why it was there.

There may be other things as well that I've overlooked, if someone comes across something that doesn't make sense let me know and I'll go back and revisit it. It has been a long time since I built the core of the spreadsheet, in fact many years. The final results however, do match our docs for various sizes and F/ratios, so it does appear to be functionally correct. For those who are looking at the spreadsheet I do recommend updating to the new version. CZ

Thanks Carl. I put the values from the SM20-047 screenshot just to check if results are similar and found some mistakes. Errors fixed, I then download the .xls file as asked to Files The Mirror Maker's Spreadsheet The Spreadsheet. It´s interesting to check the ML chart in many diameters and readings. That could de used to quantify astigmatism, maybe a 3D chart - don´t know how yet. I need some time to understand how the calculations runs through the new 7zone spreadsheet and I´m going to be very busy this week, but I already see that another auxiliary worksheet will be useful to place the calculations, keeping the main form clean. Of course comments, suggestions and other´s modifications are welcome. Ricardo Dunna I think you're doing some nice work, I like some of the features you've incorporated. We have a folder in the files section, called the Mirror Maker's Spreadsheet.

Mirror Makers Spreadsheet Functional

Very nice, Robert looks like you're the point man. Thanks for taking the job. I'm getting

ready for an intense three weeks of overseeing construction at our place (on top of running the optical shop). I'll be heavily preoccupied, so I'm very pleased this project has been taken over. Have at it, and have fun. I'll stop in from time to time and say hello. CZ

I have added the list that Carl provided for features to work into our spreadsheet. What we should try to accomplish next is to take a look at the list and look at the spreadsheet provided. We need to start working on the approach for accomplishing each task. We can be detailed about our approach because that will guide the developers as to what we want. The idea is to create a good description of what we our doing and we all agree before it gets done. So we should have good descriptions like how the layout will change when adding new input cells and exactly what parts of the calculations will need to change. This is also a good place to create a mock up version. Robert

Mirror Makers Spreadsheet Functional- astigmatism

The reason the full version spreadsheet has multiple axes inputs are because we fully intend to provide a method for evaluating astigmatism. This method is not in the literature, it was developed in-house, based on experience, and using the star test as corroboration. I've most likely made reference to it one or more times on the mirror group, but we'll go into it in detail if the mirror makers of the group are ready for it, when we have a universal spreadsheet completed. It is a qualitative analysis based on several graph patterns, which are telltale signs of various conditions, or types of astigmatism, both higher and lower order. It is in fact very effective, so much so that we are able to use it as a go, no-go criteria.

We measure every finished mirror for astigmatism, and larger mirrors long before they are finished. Don't think just because this is "ZOC" that we don't get astigmatism. Quite the contrary, every optician deals with astigmatism, and in fact that one issue is the major factor for larger mirror failure. It is the very most difficult error to control in large, thin mirrors. We have sent scores and scores of mirrors back to polish in the past because of measured astigmatism. Today it is much less, as we have learned to control all applicable variables. We use this method exclusively to determine the mirror's condition with respect to astigmatism, and it is very sensitive, as sensitive as the knifedge test itself. To date, the method has not failed us. Every professional optician of a necessity must be able to effectively evaluate for astigmatism, and I have no doubt that is indeed the case when it comes right down to it. CZ

Any other suggestions, I am not saying measuring astigmatism is impossible, but I believe it is not easily done, and before incorporating it into the spreadsheet, I think we should agree on a useful testing method. Nils Olof

Functional Requirements

Futtrich, If I'm not mistaken I think the Monte Carlo approach speaks to the issue to which you refer. It is a module in programs like Admir, and perhaps Tex, if I recall. James Lerch may have also written it into Figure some time ago. For what its worth, let

me tell you how we answer that issue here. We take multiple sets without moving anything, and compare the consistency. We don't need a graph to tell us when a plot has readings that were .005 or .007 off from one set to the next. It's pretty obvious. When we get a discrepancy of more than .002 or .003, we go back and revisit the zone in question again, to determine which measurement was off. All the work is done at the knifedge, with a pencil, in the dark room. By the time I get up from a two-direction run on a set of measurements, typically every zone except the center is in agreement by .001, or .002, at the very most.

Let me go further into detail on that. We take two sets of measurements, one from center to edge, and then back from edge to center. If a particular zone has an inconsistency we turn around and revisit it again. So a full set may mean three or more trips out and in, although we don't re-read every zone on the way, only the ones that have discrepancies. So that being the case, personally, I would have no use for multiple data lines representing each measurement set. I want that work completed before I leave the test room, because if I find out by looking at graph lines that my set was no good, then I have to go back and do the whole thing over again. That's my $.02 CZ

Hi folks, since I am not nearly good enough with Excel to contribute, perhaps I don't really get a vote in the requirements. However if you will accept a couple of suggestions from a (not so innocent) bystander... It seems to me that it should be possible to analyze multiple data sets taken in the same mirror orientation to put error bars (or lines) on at least two of the three result graphs (surface, RTA, M-L?) A "cheap" way of doing this for the surface graph would be to plot one computed surface line for each data set. If the lines agree well then the random errors in each measurement set are small compared to the measured surface deviations and the results (surface plots) are useful. If the lines do not agree well, then the surface plots are probably not giving us meaningful results and we need to make more (and more careful) measurements. It also seems that if we do this for data sets taken at different (rotational) mirror orientations, we get a check for astigmatism.... if the surface plots produced at different orientations consistently have different shapes, the mirror probably has astigmatism. As Nils points out, we are probably NOT going to get the mirror back into the same place (within 0.0005") after rotating it, and the data sets will almost certainly show systematic offsets from each other. Can we use the measurement(s) for the center zone to "calibrate" the data sets to each other?? In any case, the spreadsheet should have some capability to calculate the error in the results. Also, some capability to quantify astigmatism would be a REALLY nice "advanced" feature. Clear skies, futtrich

Measuring Astigmatism with KE Test

When two axes of orientation have third order primary astigmatism, that is, they move continually away from each other (even smoothly), in defocus, the wavefront profiles as well as the M-L graphs will have unmistakable differences. The M-L plots will continually go away from each other. The wavefront profiles will be opposite, as in, one ***overcorrected***, and one ***under corrected*** (for a balanced, perfectly corrected mirror). 3rd order is the easiest to spot, because no two zones will precisely match up. What I'll

probably do when we do get into it is provide the example of the mirror Phaseshift10, for which we have an interferogram as well as Foucault data. It shows this condition clearly. Also, and of course, we have hundreds of examples available, of tested mirrors.

Let me throw this out for those who are itching to chew on something. Steve, you picked up on the word "qualitative". Yes, indeed. When two ML plots of 90° orientation are overlaid and the majority of plots (the actual dots) will match up anywhere along the axis, it is no coincidence. The plots of a necessity MUST be operating on the same figure of revolution. The test is too sensitive to allow otherwise, as the odds of a random error matching up on the overlay mirror after mirror are of such a magnitude that is it unthinkable to consider anything other than a figure of revolution. If they weren't operating on the same figure, they could not match up. Because we have looked at hundreds and hundreds of mirrors in this manner, we have learned to identify different conditions, based on a few specific general types of patterns. We don't have to reference the centers and keep the position identical to keep the centers matched up, because they usually don't, anyway. The centers are typically off if for no other reason than it is difficult to get consistent measurement in the center. But imagine the rest of the mirror matching up, within plus or minus .001 on a fixed source knifedge. How can it be anything other than a figure of revolution? (It also says a LOT about the capability of the test!). Then over time we looked at where departures occurred, and began to find patterns. When the time comes, we'll go into the patterns themselves, specifically. But for now, I'd rather it not get into the way of the much more important and larger issue of how to figure the mirror. CZ

If the plots turn out different shapes, then yes. The problem is that pure primary astigmatism will not result in different shapes. Profiles across two axes of primary astigmatism differ mostly in defocusing aberration, and this is subtracted out of the analysis, making the plots look identical. If I get some time over the next day, or so, I will demonstrate this with a simulation. As Nils points out, we are probably NOT going to get the mirror back into the same place (within 0.0005") after rotating it, and the data sets will almost certainly show systematic offsets from each other. Can we use the measurement(s) for the center zone to "calibrate" the data sets to each other?? A difficulty here is that the center zones are the hardest to measure accurately, so getting within .001" would be problematic. I am very curious to see Carl's method for detecting astigmatism. Carl mentioned it's not quantification, but a go/no go test. -- Steve Koehler steve_koehler@s...

Steve, At this point I have one question: You show two identical parabolic curves from zone one to zone 9. Forgetting the center of the mirror (where you put your theoretical astigmatism), what must be the difference in radius of curvature of these two parabolic curves, in order to have them identical as they are, and yet be astigmatic with respect to each other by 1/4 wave?

Carl As far as I can tell, there is no discernable difference in the knife-edge readings (other than a focus shift) or in the resulting RTA analysis (once the point of best focus is found). -- Steve Koehler

Steve, I posted the question again different, but decided to scratch it. I eliminated the posting, so as to not add to the confusion. I appreciate all the work you did to answer my first question. I think the graphs were correct, and predictable, based on your model. Here is the problem- I maintain that you can't offset two parabolas on the same glass such as you have done. You can simulate it, but you can't fabricate it. I think Nils is on the same wavelength here when he says it will not occur naturally. That is indeed the case. The assumption that led to the simulation is, in my judgment, faulty.

Let me try it again, this way- if you want to understand real astigmatism, go to the grocery store and buy a can of Pringles Potato Chips (I'm serious!). I would recommend a careful study of the shape of the ones that are not broken. There is a reason that we call an astigmatic mirror a "potato-chip", and that is why. Pringles are a perfect potato chip, and they perfectly represent astigmatism. What is primary (two-foci) astigmatism and how does it occur? First, as Nils pointed out, it will have roughly a common center. There is no way you can create in reality two perfect parabolas of the same focus and arbitrarily offset them by .003. What happens is then you have four lines across the mirror at which you have to trace a shift between them. Up, then down, then up, then down, an exact distance, same from center to edge, with same deviation along a straight line. -Never going to happen.

Astigmatism happens because of a *bend* in the glass. Support the glass in the center and bend two edges across from each other down. What happens? The other two edges bend up! What does that create? Real astigmatism, with zones progressively moving away from the parabola, long in one axis, and short in the other, but all having a common center. Each zone shift is progressively longer than the perfect parabola than the zone before it in one axis, and in the other axis it is progressively shorter. They do not progress in a straight line. Physically, it just isn’t going to happen. The model that was created, in my understanding, is not real astigmatism. At least it won't occur in any approximation of reality. You might call it astigmatism, and in a technical sense it may qualify, but I don't think you'll ever see it on the glass.

You can go to the image Phaseshift10 and real astigmatism is seen there. It’s in the bench images folder. Look at the center. Understand the color sensitivity is very strong and the error is very weak, but nevertheless see that the center is largely the same, being light green and light blue, and roughly a figure of revolution. Then as you go away from the center in two opposing axes, the colors progress in opposite directions. That is real, two-foci astigmatism. (Note that the total error on the mirror is 1/7 wavefront, so the total astigmatism is only 1/14 wave per axis at most, so it is not as strong and smooth as a 1/4 wave example). When we measure that mirror with the knifedge, each progressive zone goes further away from the parabola in the ML graph, in one axis going long, and in the other axis going short. Our measurement agrees very well with the interferometer.

Bottom line, when we measure two axes of orientation that show exactly the same knifedge progression, we assume we're looking at a perfect figure of revolution. And no test (star test, most often) has ever said different. We've fabricated now well over 1,000

mirrors, and have not seen any evidence to date to show our assumption as wrong. Sorry to drag you all around on this one, I should have gotten straight to the point, but I wanted to work with your model to point out what I believe to be the error. After further thought I realized there might be no way to do it, outside of simply stating that the model doesn't match the physics. Carl

Carl, You show two identical parabolic curves from zone one to zone 9. Forgetting the center of the mirror (where you put your theoretical astigmatism), what must be the difference in radius of curvature of these two parabolic curves, in order to have them identical as they are, and yet be astigmatic with respect to each other by 1/4 wave? I put another graph ke_astig2.png in Koehler/Files. In the bottom plot, I show the ROC for the zones as a continuous curve. (I did this by simulating a moving-source KE test with 100 zones. The KE readings for a moving source test directly measure the ROC). As expected, the red curve has a longer ROC than the blue curve along its entire length. The difference is about .079 mm (.003"), as measured at the center of the mirror. The interesting thing is that the red and blue ROC lines are almost identical in shape. They are slightly different, but only on the order of magnitude of the surface deviation from the perfect parabola (i.e., very small). I think it is the extreme similarity in shape of these curves that makes it so hard to quantify astigmatism with the knife-edge test. Once the M-L analysis has found best focus, the red and blue lines almost exactly coincide. To directly use the difference in ROC between the red and blue profiles to quantify astigmatism, it would be necessary disturb the relative location of the mirror and the test rig by less than about .001" across the mirror rotation. -- Steve Koehler steve_koehler@s...

John, what a wonderful story, I love it! And I'm very pleased to hear about Bob Goff helping you, very fine, indeed. What you did is one step further than what we do here. We only test for figure of revolution, we don't hand-figure to fix it, and it is just sent back to polish if we screw up, but you fixed yours! I'm really impressed! Thank you for telling us your story, John.

Carl Hi All, I've only been lurking in this group but this problem caused me no end of grief for a large mirror I was making so please permit me to outline briefly how I addressed the measurement problem. Some time ago I was in the process of fabricating a 32' Hextek blank. Aside from the print through problems I was faced with a severe case of astigmatism. In order to take zonal readings over different mirror diameters I was able to locate a 3" rotary table with a center hole. The knifedge was mounted to the rotary table over the center hole and the whole affair then attached to the moving stage of my tester. This allowed me to take readings every 15 deg. (the table was marked in deg.) without disturbing the mirror, only had to rotate the Couder mask. After determining where the short axis of astigmatism was, and with help from the late Bob Goff, I was able to lengthen this axis to match the long axis and then finally continue the figuring. BTW, the measured difference between the two axes was .024" at the 70% zone, moving source used. Thanks for reading, John Vogt

<John.R.Zeigler@m... wrote: I was able to take a look at the 7 zone sheet last night, and I

believe that cell P23 is used for this purpose, but I have not spent enough time digesting the rest of the sheet to figure out why the value is 21.6. The comment next to this cell "Units (21.6 sets wavelength to 550 NM)" does not make sense yet, but I am sure that it will soon. If I were reading this correctly, then this number would need to be changed or converted in order to enter Metric measurements. (Carl, does 21.6 change the formulas to use 550 NM instead of ~650 NM, or more specifically 552 NM instead of 650 NM?)

John, I have to beg ignorance here. I think that changing the unit slightly will change the wavelength and consequently the size of the diffraction disk, but I don't know how much in what direction does what. I didn't create the core math formulas, or even construct them. A programmer using Genmir, written by Dick Suiter, did it. The programmer got an Excel file to reproduce the Genmir output and then I constructed the layout and graphs, and how it worked together in the spreadsheet. Nevertheless, here's what I can do. I have uploaded a file to the files section in the spreadsheet folder (ZOC generated files). It is the BASIC program listing for Genmir itself. You programmers out there can have something to chew on, and when you figure out the answer to John's question you can tell me, too. If I am correct with the cell location and conversion as mentioned above, I will upload a spreadsheet that has these changes.

I will also look at why this value is 21.6 and add a cell where you can enter the wavelength in nm to make it easier to specify what color your light source is. John, if I'm not mistaken, with reflective optics the wavelength of source light used in a knifedge test does not affect the geometry of the test, so it’s not about the source light. The wavelength in the spreadsheet concerns itself with the color of light observed, that is, what is most sensitive to the human eye. We use yellow-green, at about 550 nanometers. Correct me anyone if I'm wrong, but I think that is the case. We don't go changing the diffraction disk depending on our source color, but rather what wavelength the telescope will be operating at. Carl

Measuring with Foucault How?

How interesting, and perhaps strange but no, we did not have a telescope on a tester in the measuring room. Yes, we do have one tucked away on a shelf. No, we do not use it for assistance when measuring, although I did try it for a while, and seem to prefer naked eye. Yes, we do use it for photography, for taking the images that you have seen under the knifedge on the mirror group. Perhaps you stole a glance of the one on the shelf in the shop when you were here, but I don't recall we made any talk or issue about it. A student of Picasso...on Hilton Head...you do get around. Carl

Good Evening Carl, In but again venturing back to our visit, I seem to recall that on your Foucault setup...there was a small scope that could flip into position to view the knife edge mirror image under magnification... Was I seeing things wrong or do you use assistance in doing Couder mask measurements???? My mind keeps giving me images of you and your shop...it's a curse, that I love :<) Preston Having just returned from visiting a student of Picasso's and having a wonderful time in Hilton Head...I'm glad to be back with the group

Futtrich, I'm always happy to see amateur astronomers, whether they are ATM's or not, making the effort to bench-evaluate their mirrors. It is on the bench that one begins to see very clearly the workmanship that was put into the optic (or not). One of the reasons for our former documentation was to provide information to those who actually measured their mirrors. It has been done a number of times that we know of, however the overall percentage of our mirrors tested by their owners on the bench is rather small. I think probably other professionals, for various reasons, have tested more. As far we know to date, every report of a mirror tested by its owner with a knifedge came within 1/50 wavefront of the documentation, for their averaged set. I think that says a lot about the capability of the amateur community to measure. My best wishes as you evaluate your mirrors. CZ

Carl, Thanks for the info on how you handle getting a consistent well measured data set. Yes, I had noticed that a couple of the analysis programs could use multiple data sets to get a measure of the accuracy of the final results. Your approach seems much simpler. I just finished my KE tester. With a little bit of luck, I will finish the mirror stand and masks this weekend and take my first sets of data. It is monsoon here in Tucson, so clouds are likely. That will give me a much better feel for how real numbers "feel". I have what I think is a ~1/4 wave Meade 16" and an 18" Galaxy mirror that I think (based on star tests) is MUCH better than 1/4 wave. That should give me some good and some not-so-good data sets to play with. I am really looking forward to seeing if I get numbers that make sense and if the measurements agree with what I see at the eyepiece. It will be nice to actually make some measurements for myself. I am planning to try out several of the analysis programs / spreadsheets to get a feel for how they work for me. I find that I can't really evaluate a tool without trying to use it to do something useful. I am planning to take several data sets and run them through separately to see how much my errors influence the results, then I will have a feel for just how close two data sets have to be before I believe that I have a good measurements...part of the learning process. Anyway it should be interesting. Clear skies, futtrich (myron calkins)

Changing Center Mark

Gary I'm answering because we made the mirror, but don't consider my input here the final word. See if others will contribute. I agree, I would be nervous, too. I have a personal rule that I don't put any solvents on my mirrors. Now I do understand that theoretically it is possible to do so, and I hear of it being done, I just don't do it myself. I think polish remover is actually acetone. If your reinforcement ring is the cloth type it will soak it up. If it's plastic, well, the acetone will melt the plastic. So in either case it will probably loosen the ring. I would say there are three possibilities.

My second choice would be to place something soft on the glass like cotton or such so you can rest your palm near the work. If you have very steady hands, I might take a single edge razor blade and try to pry the edge up. Yes, I know that sounds even scarier, but if you're careful, the most you will do is create a miniscule tick in the coating. It's all under the secondary, so no harm. Then when an edge is up, I would gently pull on it with

tweezers. It might just come up clean.

The third choice is the solvent. I wonder if alcohol would loosen the glue. I would rather do that than acetone. But in the last case, acetone will likely do the job, but it may also leave a residue from melted plastic. Other opinions are encouraged, group.

Oh, and my first choice? Collimate with a sight tube and Cheshire, and if you have a very fast scope, such as F/4.x, then finish up with a laser as per the manufacturer, Starmaster. They really are good enough :) CZ

Hi everyone: I've decided to remove the reinforcement ring marking the center of my 14.5 inch ZOC mirror, in order to place a triangular marker to use with the Catseye collimation system. The instruction is to use a "q-tip" to saturate the ring with fingernail polish, and to work it off the mirror when loose. I'm pretty nervous about this. Has anyone else done it? Are there any other methods to consider? Can the polish remover damage the coating? Does it need to be rinsed off or just let it dry if it's confined to the center? Thanks for any advice. Gary

Figure & Contrast / Auction Astromart

Well, Michael, I note this is the first time you have ever said I was wrong. It's about time:) I suppose Z-mirrors would be worth more as well, if we didn't make so darn many of them <G. Thanks for the most interesting information. I'll be sure to adjust my quotation for future reference. My hat is off to the "real men". Yes, they may be lonely, but look at what they will be able to take to bed with them. CZ

Carl, You were wrong about the $10,000.00 US for a well-made Maksutov. I've been following an auction on Astromart for the scope you mentioned. The bidding is already over $19,000.00 and there are still 5 days left in the auction. I'm assuming the real men (single or widowed) will step up in the last few hours....;-) http://www.astromart.com/auctions/details.asp? Auction_id=285&bidhistory=1 Perhaps you should consider adding corrector plates to your line up after all...;-) Regards, Michael Gilbreath

Minutes and Micro inches

Ricardo, You've been a busy guy. I haven't looked in detail, but at a glance its looking good. The reason we use micro inches and label the left side of the graph as micro inches is because we have a direct correlation to figuring time, which I will be teaching when the time comes. It has to do with minutes and micro inches. Right now an explanation would be somewhat meaningless, but there is indeed a reason. I don't know everything about Excel, in fact a very small percentage, only. With our former documents we had a legend on the right side that was a vector graphics object overlaid. When the graph was in its final format (size) for the finished mirror, the legend lined up with the wavefront lines, above and below the parabola on the wavefront graph. It depended on the particular mirror, as which tolerances were listed and how they were labeled. Those boundaries

above and below do in fact represent wavefront tolerances, probably 1/10 and 1/15, or such (I would have to look it up). I don't know how to have a dual legend in Excel, one on the right and one on the left, but if we could do that, it would have wavefront on the right, corresponding with those tolerances. (Can we do that? It would have to expand and contract with the graph as the values change, so it would accommodate everyone). That information was for the final owner. But the info on the LEFT is for the Mirror Maker, and it is micro inches, and I wish it to stay that way. Good point, I'm glad you brought it up. Carl

Hi, I updated my spreadsheet file on Files section. What´s the meaning of the 2,2 and 1,46 at Wavefront graph? Wouldn´t it be better to see this vertical axis in wavelength? Regards Ricardo Dunna

I'm going to go on a rant and probably piss some people off. Maybe its time for a housecleaning, anyway, if I'm not mistaken, Ricardo has been working solo, and other than a partial by John, that's it. Now Robert has made a good faith gesture and made a function chart and a mockup. He volunteered to be a clearinghouse for the project but it seems to me no one is paying attention and to me that borders on being rude. This is an exercise in ATM's working together.

Again, at the risk of pissing people off, but certainly not to diminish all worthy effort made to date, do we all have such egos as that every one of us is going to do it all alone? I know for certain that *I* can't. How about some of the volunteers having the grace to answer Robert, tell him what they are wishing or willing to do, and then get some correspondence going BETWEEN us all. I've not seen one person say, "Yes, Robert, I would like to work on the x-module". You know, I'm not terribly surprised to see the state of the ATM community the way it is. There was a time when ATM's could outgun any commercial mirror made. Not any more, folks! Before one individual by the name of Dennis Rech, Tom Waneo made the only well-known machine for the ATM in circulation. And those of you who know that machine understand my drift.

The technology we professionals use has been there at least since WWII! We professionals are using machines that were designed sixty-five years ago. The point is, they have ALWAYS been there and just now, in the Year of Our Lord two-thousand-and-something the ATM community as a whole is barely beginning to realize how to grind and polish a mirror efficiently using a motor! (Thank you, Dennis. I'm delighted someone finally did it). And here's a sad thing. The distance between Dennis and myself is about 25 miles as the crow flies. The reason I'm in the position with machines that I am is because of Dennis and the reason Dennis is in the position he is with machines (and why he started it in the first place) is because of me and the reason any of this exists is because we COMMUNICATE AND WORK TOGETHER. Talent residing in a twenty-five mile radius created what you see between ZOC and the Mirror-O-Matic, two major, unprecedented forces in amateur astronomy! Imagine...just imagine what would happen if ATM's across the country actually worked together on developing things! How much talent lies out there, isolated, waiting for the other parts of the formula, to create something truly great? What we have as an ATM community is pockets of stuff here and

there, individuals make most all of which, alone.

I'll tell you all something I've never said before. The reason we have the success we do is because what we do here at ZOC is greater than any one of us, individually. *I am not* Zambuto Optical Company. ZOC is a combined effort of many, many people, some of whom you know, and some of whom you don't. This stuff is big because I don't try to do it all myself. ZOC is an idea. It is a concept; it is about something that is much, much bigger than myself, or any one who is involved in the effort. In fact, at its core it's not even about anything associated with a name, but people have to have a way to identify it, and that happens to be the name that is used. It is, in fact, much bigger than any name. The concept that is behind and drives what we do is something that I can only contribute to, but I am not *it*. If you want a clue as to how to create something big, I'll give it to you. You have to engage multiple minds, and get them working TOGETHER. When are we going to stop being so darn isolated and start communicating and working as a team? You all want a great spreadsheet? You want something that is greater than any one person can create? Then step back and realize that what we want to accomplish is greater than any one of us, and start working together. If you do that, the spreadsheet will only be the beginning. There is no telling where you may all have the privilege to travel after that... May I'm all wet here. If I am, then please forgive me. I hope you all understand the spirit of my lecture, and that no one takes it personally. (... Otherwise, I imagine the membership will drop by a hundred or so, shortly.) End of rant. CZ

Thank you everyone who input on the rant. I see clearer now, and yes, I'm here to learn along with everybody else. I have stuff to contribute just like everyone, but I don't have it all. Ricardo, Ditto on John's comments. Hey, would you do something for us- would you be willing to teach us about your spreadsheet? John recognized things in it that not everyone will, and just the mention of those things helps to awaken the value of what you have done. So would you be willing to give us a primer on it, either in the files section, or here on the main post list? And if not, then John, or anyone else would be welcome to. I'm personally interested to learn about the macros, where to find them, how they work, and so on. But I want to know all about it. I would like a walk-through. I agree with John. Ricardo has taken the full spreadsheet and done the most work, which qualifies it as our next benchmark. So we work on Ricardo's doc as our next launch pad, and keep communicating as we go. Again, Ricardo, if you're willing, we would like to hear all about this document. Don't be afraid of going on too long. Tell us what you have done, and why. Teach us how it works. Teach us how it is put together. I'm sure that many of us will benefit from this. Oh, and thank you for your contribution. CZ

Ricardo - Awesome work, did you address all of the modules that were on the wish list? I see Metric, Multiple zones, Moving or Fixed source (partial), Lambda, Zone Centers, and the ability to set any zone as a referenced zero point on the graph. You have even added the ability to double-click on any of the knife-edge readings individually, by rotation, or the whole group and have those readings used for all of the graphs and calculations. Great feature. I have looked over the VB code you have in the background, and I see that you have started to use named ranges for many of the calculations, and added many comments to the code. This will help a lot with the collaboration effort.

Robert, Ricardo, and everyone else, since Ricardo has addressed so many of the items, I think that it may be best to use this spreadsheet going forward. There is still work to be done in this sheet, but I think that since much of the work is already done that it would be best to go from here, and start by testing Ricardo's sheet. What we need is a method of source control. We now have two very good foundations to work from. What version of the spreadsheet will each of us work on?

I am not sure how to answer this dilemma, and this may be a reason for the lack of response from many. I would imagine that we would need a human to collect all of the modifications and merge them all into a single spreadsheet to redistribute to everyone working on the project, which would then become the next foundation for additional work. Would this be Robert, or would he be considered the project manager? If there is no one else who wants to do this, then I will volunteer for this task. Robert, Ricardo, anyone else? Let's all get together, decide who will be working on what, and get this project going. But let's not forget what this is all about. This is the development of a TOOL to be used to assist all of us in the process of making and testing a telescope mirror. This is just a tool, nothing more, nothing less. John R. Zeigler

Discipline in the Spreadsheet Project

Ricardo, I have some comments after spending about ten minutes with your latest version. I'll limit my comments to my observations in that timeframe, because a good list has cropped up, good enough for the moment. The reference zone slide bar is a slick feature, but it doesn't work in sync with the slide bar on the ML graph in the sense that once the slide bar on the ML graph has been offset from zero, the reference zone slide bar is off calibration. Furthermore, the reference zone slide bar has eliminated precise control using numbers. (Where is the COC constant input?) We measure with numbers, and we reference numbers. We won't always zero out a particular zone, and we need the SAME precision as exists in the spreadsheet I wrote, that is, four digits on the right of the decimal point.

Next, the graphs are not tied together by the slide adjustments. If you look carefully, you'll notice that adjusting my one COC constant moves all the graphs simultaneously. The purpose for having all three in the picture is to be able to see all simultaneously at same focus. This is critical. Next, the edge position for the RTA graph has been eliminated. So that precision is gone as well, so much for controlling the edge.

Next- I set up the wavefront graph the way I did for a reason. In this case it was to provide perspective to as close to the center of the mirror as possible, because this math will always tie the center of the mirror to zero. Seeing the mirror as beginning at two and a half inches is not so intuitive to the mirror maker. That's all for now, and I'm going to write to the group as a whole in general on this subject, next. Carl Folks, I wish to express some concern. First I want to provide some perspective. The spreadsheet that I uploaded to the mirror group looks simple enough to the programmer. A good programmer can slice and dice it up in an afternoon, and make a nice gizmo out of it and get it to do trick things. But can it make mirrors?

We spent two years developing the design on that spreadsheet. It took TWO WHOLE YEARS. Why so long? Because it developed AROUND a process of mirror making, that developed over a period of time. The spreadsheet evolved over that timeframe, continually, feature by feature, and in fact it still evolves even now. That spreadsheet as I uploaded it is an extremely powerful tool (You don't know what you have in your hands). It knows how to provide precise information to the knowledgeable mirror maker who knows how to use it. But no one knows yet how we use it, because it isn't universally usable, according to the consensus of this group. I'm going to put my foot down as far as my participation goes. You as a group can do anything you wish, but I'm asking that a committee of two or three who are dedicated to the spirit and practice of this project as it have been lined out forms. (I like the kind of talk I was reading from John Zeigler and I think he's on track). All work that is going to be done should be done on a main document chosen and approved by the committee. They will also approve each piece of work that is done on that core document. Changes will take place one at a time, and they will follow the outline of what needs to be done to get international use. I will not be on the committee, but I'm willing to advise it. That way it belongs to you. That is my suggestion.

For those who don't understand my core intention for a goal, here's the deal, in a capsule. If everyone who didn't use a fixed source tester were willing to multiply by two, and if everyone who measured in millimeters were willing to multiply by 25.41, and if the group were willing to do what we do and use five documents (one for each number of zones) to run our entire business instead of one, we would already be under way making mirrors. Get it? But because the consensus of the group is unwilling to multiply millimeters by 25.41, double their inputs by two for a moving source tester, and have in their possession five of six docs instead of one, we're going through all of this. Okay, fine, but look what's happening when we complicate things further. (Which method is more complicated, I wonder?) What needs to take place initially is to get the same precise document functions to be able to be used internationally.

Once that is done, we can go on and if anyone wants to make a more complex doc on his or her own after that point, that is fine. But that will not necessarily be the document that this mirror maker teaches from. I'm going to be very frank here. Having individual efforts change anything and everything they want because they think it will be a good thing isn't going to work, at least not for this mirror maker. Its not that I don't appreciate and respect the talent and the effort, but rather that I can't use it. So, if you want to exclude what we at ZOC have to offer, that's okay, I really don't mind, as I have more work to do here than I could ever hope to accomplish. Choice is yours. So we'll see if some leadership forms, and if the group can establish a disciplined approach to the project. I'll stand by as advisor as long as I'm being included. But as soon as the core document I uploaded gets massacred, I can't help anyone. I'll just move on to other things. What I've given you for a start is the best of what we have. What you do with it now it up to you. CZ

Thanks, Preston Perhaps you could go see Robert and create a small core group. You have some understanding about why we're doing what we're doing; I think you would be

good in that position. Additional thoughts on design (thinking out loud)- if folks are willing to "think" in Imperial measurements on the output only, (because that is what we use and teach) it would be rather simple to input in millimeters where needed. It only takes one cell as a qualifier to input on the front end to make the conversion right off your micrometer. Then the entire spreadsheet remains the same, otherwise. One benefit is when teaching is going on, we're not talking in two formats simultaneously. That's just a thought. Carl

Carl, I fully agree that spending time to incorporate all of the various possible bells and whistles for multiple zones, fixed vs. stationary, inch vs. mm, etc. will take away from the purpose of this exercise. And as you said, there are some really talented programmers working in the group that have put up some very nice work but you cannot take the time to try and teach from something that you also have to learn and trouble shoot. I have no problem dividing by 2 for the moving source or using the correct multiplier for metric. And 5 documents for differing amounts of zones that work and allow you to help us learn how to use these documents to better make mirrors is what I'm here to learn. As I originally stated, my Excel is weak...but if I have to bone up on it to help with your software so that we can all learn about using the software to better make our mirrors...than so be it.

Having seen your software in action at your shop and how you use it, I think this should be in everyone’s interest to use what you can teach in the way of what works for YOU i.e., your original document. I'll work with anyone that is so inclined to do what you have asked. Best Regards, Preston

So we'll see if some leadership forms, and if the group can establish a disciplined approach to the project. I'll stand by as advisor as long as I'm being included. But as soon as the core document I uploaded gets massacred, I can't help anyone. I'll just move on to other things. What I've given you for a start is the best of what we have. What you do with it now it up to you. CZ

It appears a core group has formed, and I think Tom Karpf will probably want to be involved. I just heard from him today, the poor guy returned from his vacation to a crashed hard drive. He will need some time to catch up. In hindsight it probably would have been easier on the team if I had created and uploaded a 9 or 10 zone, because it is easier to take cells off the front end than add them to the back. But it is doable. Just keep in mind that at the end of the RTA series and wavefront series for example, there are some different calculations. Once the team has developed what they feel is necessary for ATMs to be on the same wavelength with our shop, we can get to mirror making, learning some technique for figuring by overarm machine. Thanks so much, folks Carl

Sounds Great Robert, Other than the fixed/moving cell, only the 9-zone will take some additional work. I think in creating the 5-zone that we can just delete parts of the spreadsheet, though it's been a while since I've done any Excel. I did look at Carl's formulas yesterday for several hours and some of it is coming back. This should put a :<) on Carl's face. Regards Preston

Once we have that we have a set of sheets everyone can use and we can make mirrors instead of spreadsheets. Robert

OK, How About Some Data

Okay, some data! I have uploaded the data from my first set of KE measurements, taken this weekend. The mirror in question is from a Meade SF16 DOB. It star tests at about 1/4 wave and the ronchi eyepiece shows progressive deviations at the edge. I have always thought that the middle of the mirror looked good with the Ronchi eyepiece, but at 72 LPI, it is HARD to tell. See how insensitive the Ronchi screen is without a Barlow? In the KE test, the surface looks VERY smooth. There are no small-scale features at all as nearly as I can see. I have tested a Meade 16 that was very similar. I took five sets of data at a single angle. I plan to take more data at other angles, but the scope has never shown even a trace of astigmatism at the eyepiece. The first two data sets were much more scattered than the last three, so I called the first two "learning" sets and threw them out. The offsets among the last three sets were 0.015" and 0.021". When the offset is removed, these three sets agree within 0.003 for each zone.

First, a beginner's question is this data good enough to bother looking at or should I go back to my garage and take more and better data. It depends on what you want to do with the data. For general evaluation purposes, I think the data you have is fine. I would not be at all offended to be told to go make more measurements, so if that is the right answer, please say so. A second question (assuming that the data is good enough to look at): Am I right in believing that if I mask the mirror to 14 inches it should perform MUCH better?

Yes, at 13.5 inches the mirror should perform better. I set the COC adjustment factor to 70 to move all the error to the edge and it looks like only about 1 inch along the edge is a problem. The same as the mirror I tested. It was also smooth, and quite under corrected in the edge. However we don't look at it that way, from the way we figure mirrors (the way you had the graph set). There are shops out there that will take the edge down, and see it the way you had it configured. Some such shops have TDE in their final product. We instead go the long route. We remove glass from the entire mirror and bring it away from the edge, accomplishing the same thing. One reason is that this method when done properly will perfectly balance the edge every time, by default. (See also below) The third question: Probably just out of curiosity, but.... (This is how LONG projects get started).... IF I were to consider trying to fix the mirror, how do I use the spreadsheet to guide me?

Okay, here is the simple answer, and the way we look at the mirror according to the methods of figuring that we use in this shop- Zero out the edge zone by typing minus 187 into the COC constant adjustment cell. Look at the wavefront graph and see those 27-1/2 micro inches of glass on the wavefront need to be removed (smoothly) from center to edge to fully correct the mirror. Then it is done. If this is not a good mirror to ask that question about, just tell me so. This is a great mirror to ask that question. It is a good candidate for refiguring being as it is smooth and has no astigmatism that you can detect

at the eyepiece. All it needs is to be finish-figured until it is fully corrected. They just didn't finish the mirror, which is very much the same as one I tested years ago. I am learning a LOT just trying out the various spreadsheets and programs. If I actually were to decide to try to do this, I would have to start with a smaller (8 inch?) mirror to learn mirror making, so this would not be a short-term project. Agreed, I would not want to try to finish a 16" mirror with such potential with little or no prior experience in mirror making. I'm pleased you used the spreadsheet, and did so with great success. If you have any other questions about the figure, how to read or analyze it, etc., don't hesitate to ask. CZ Clear skies, futtrich (Myron Calkins)

I didn't get into any more detail on using the spreadsheet to fix the mirror because from your writing you're not yet a mirror-maker. Other than to show how we look at it (below) the next thing to do is to get into the actual decisions on how to go about it. -Not as simple. If and when the time comes, we can approach the situation as necessary. Keep in mind the method we use employs a machine, where we perform what is very much like hand figuring with sub-diameter laps, mirror face up. There are actually two ways to look at the mirror. One is the way I indicated already, and the other is the way you set it up. One could say (with "70" in the COC constant box) that all that needs doing is to take the edge down and that would be true. But doing it smoothly and without TDE may be another story. I will also note that the greater part of the mirror is, interestingly enough, inside the M-L envelope, which demonstrates it is rather smooth. Five out of seven zones are in. I could also mention that the methodology we use when employed with a bit of expertise could smooth the center zones even further, bringing them even closer to the parabola, while correcting the edge. This is not a difficult thing to do with the right size lap. Again, this mirror is a very good candidate for making a truly superb mirror, if all other factors are in order. CZ

IF I were to consider trying to fix the mirror, how do I use the spreadsheet to guide me? Okay, here is the simple answer, and the way we look at the mirror according to the methods of figuring that we use in this shop- Zero out the edge zone by typing minus 187 into the COC constant adjustment cell. Look at the wavefront graph and see those 27-1/2 micro inches of glass on the wavefront need to be removed (smoothly) from center to edge to fully correct the mirror. Then it is done.

There is nothing wrong with looking at the mirror the way you did. There are mirror makers who would love to have that situation as their last (perhaps) figuring session. The issue is, we don't practice or teach any method for removing glass from the 70% zone outward. That requires a lap running around the edge, and has historically been a major cause of TDE and surface roughness. I don't mean to say it can't be done by a practiced mirror maker, because it can. We just don't employ it here in this shop. CZ

Yes, I see, the idea is to set it up so that the glass to be removed varies smoothly across the mirror, rather than just being all lumped up at one radius (in this case at the edge). I think I just learned something important, I was looking at the edge and not seeing the "whole" mirror.

ML and Wavefront

Preston, John has it nailed. Let me say it again, in a different way. The knifedge readings indicate the slope of the glass, which does not change, thus the percentages remain the same. That is ML and RTA. But when you change your center of curvature constant, you are changing the focus point for the mirror, or the place from which you are observing that slope on the glass. ML and wavefront are two entirely different functions. What happens when you change your focal point is, in effect you're looking at a different potential parabola. The COC constant movement in its purest form is a *mathematical focus shift* closer to, or further away from the mirror. Note again the ML/RTA graph does not change from one zone to the next, they all move up or down together. But when you change your focus point, you are changing your perspective of every area of the glass. -That IS the incoming wavefront and will be reflected on the wavefront graph. The incoming wavefront is a combination of the shape of the glass and your chosen focal point.

For example, when we zero the edge zone, we are finding the focal point for the edge of the mirror. Then for figuring purposes, we will excavate the remainder of the glass in the center to produce that parabola, as defined by the edge zone. A study of the caustic would certainly apply to this subject. CZ

The Percentage Correction cells would not change when the COC constant is changed. These calculations are a relationship between the knifedge shifts between zones as related to a theoretical knifedge shift of a perfect parabola. Looking at your data, between zones 1 and 2, you have 133% correction. This tells you that the knife-edge shift between those two zones is 133% of ideal. The Center to 70% reading compares the total shift between zones 1 and 4, 70% to edge compares the total shift between zones 4 and 7, while the overall correction compares the total shift between zones 1 and 7. These percentages do not look at what happens between these zones, just the TOTAL shift between them. The COC constant is used to shift the graphs to allow the mirror maker to better understand what the surface of the glass is doing, and adjust the graphs to show the best location to continue removing glass to best suit their technique. And of course your little thingy every so often Carl :<)

O.K. You have MY curiosity. You MUST inform me what that "little thingy every so often" is in reference to, even if you must contact me offline. John R. Zeigler
Re: "The little thingy" (was: Data in Carl's 7 Zone sheet)

John, What Preston is referring to, is a movement in offset position every once in a while. We don't leave the offset in one place for too very long, it varies typically from one to as long as nine minutes, depending on where we are in the process. That is key in part to the smoothness of the large-scale surface. I think Preston may have been impressed by the mechanical method by which we accomplish this. Our figuring machines are designed so that the quill position change is an almost effortless movement along the overarm, and done very quickly.

Strasbaugh machines, for example, do this very well. This offset movement can be likened in part to the randomness of the offset aspect of a stroke pattern when figuring is done by hand, and/or also to something that is purposeful, like a slight "W" stroke, for example. CZ And of course your little thingy every so often Carl :<)

Good timing

Dave, I've been waiting for someone to come along who wants to do precisely that. The way I acquired the archives was to start at the beginning and clicked on "expand messages". Thirty or so will load onto the web page. I select all text via the keyboard shortcut and paste the whole thing into a word processor. Run to the bottom of the page and click "next", and the next 30 will load. So I have a copy that I update about every 500 messages, and keep word processor documents for every 1,000 postings. It doesn't take very long to get 500 postings that way, perhaps 20 minutes. The time involved will be reading and cataloguing them by category. If you choose to do that, you can keep an index as a text file (or any other kind of file you wish) in the files section. I would suggest that there are postings occasionally that don't have value other than some correspondence between members and such could be eliminated. If you decide to do this, I think it could be a service to the amateur community. Welcome aboard, CZ

I joined the group about three weeks ago and it looks like my timing was very good. I feel like a freshman trying to get up to speed with the rest of the group and do not want to waste everyone’s valuable time with dumb questions. I built a MOM style machine, which is the only experience I have had with mirror making. I admit that I believe I have done everything wrong and the hard way but I know that I have been bitten by the bug and will always have a glass project going. I started with a 10 inch plate glass F5 that I never did get figured before the lap sent it crashing to the garage floor. I polished a 16-inch F5.5 while I waited for a replacement and have the 10-inch also polished out. I have (2) 6 inch F10's that are polished but need to have a TDE removed. Thank you to everyone working on the "project". I won't presume that I can make a meaningful contribution after seeing the ability of the current "committee" but I do want to express my gratitude and possibly make a contribution to the other novices that are in my position. Is it possible for me to dump the archives in a format that I can sort and manipulate? I want to make a FAQ's or category index so that if someone has a question like "my Foucault tester has a tilting knifedge similar to the Stelephane design is this sensitive enough?" They can find the answer to that question more easily. I feel like I am wasting everyone’s time discussing items such as this. But I would be willing to put together a primer from the archives or maybe make a categorical listing that the "experts" could comment on. Thanks Dave Hakenewerth Lone glass pusher from AR

"The Little Thingy"

"John" <John.R.Zeigler@m... wrote: Carl, with the design I have seen in the pictures on this site, and with the design on my mirror-grinding machine, there are two very easily adjustable offsets. The first offset is the pins location in / out from the arms pivot point.

In our shop, we call that "offset". The pin (or quill) will adjust in offset from center where a zero position would stroke through the center of the mirror.

The second offset is the left / right swing of the arm. We call that "stroke length", and we balance it more or less evenly on both sides. Stroke length determines how far the lap goes over the edge of the mirror (or not) when going across anywhere near center offset. Both are easy to adjust, and could be adjusted while in motion as long as the fingers were kept away from the pinch areas on the articulated drive, although I'll bet that the adjustments are made while the machine is stopped as is pictured on your certification sheet. Stroke length is adjusted by the eccentric drive, and must be done while the machine is off.

Offset, on the other hand, can be done while the machine is in motion. My question... Which offset adjustment, provides the best results? You have to have both. Neither one works without the other. In the photo, I'm adjusting the stroke length with a ruler at the edge of the mirror, gauging lap overhang, which we adjust by 1/8-inch increments. The other adjustment, offset, has a ruler on the top of the overarm. We adjust that by as small as 1/8-inch increments as well. Think about hand figuring- Depending on what you want to do; you use different length strokes, and different amounts of offset. We do the same thing here. CZ

Now I've just need to get the turntable mounted and get some glass spinning. Then it's time to convert hand knowledge to machine knowledge. Thank you for your time and willingness to teach. John R. Zeigler
Since John has begun addressing machine functions and what each component does, I think its time to upload some information. In the mirror maker's spreadsheet folder (main) find "***machine top***".

NEED PHOTO HERE

This is a photo of the same figuring machine as is pictured on our new certification. We have five figuring machines on location here, this one is a good representative of medium size, such as can handle 14.5" mirror with no problem, and can work up to 18" mirrors on a limited basis if necessary. The machine is a fixed-ratio overarm figuring machine, custom designed and built to figure mirrors the way we do it. It is not a polisher. Its only motion is a back and forth motion of the overarm, with a ratio between 5 and 6 to one, overarm stroke to table rotation, respectively. The eccentric slot on right adjusts the stroke length. The sliding quill receiver on the overarm adjusts the offset. What I use to work is shown in the photo. Cerium, ruler, pen, timer, and of-course when operating, you would also see a mirror and lap. The variable controller pictured lower right is wired as a DC drive. We have continuously variable speed control, which we find helpful for different applications. It is possible to do the work at one speed, in which case about 20 to 25 RPM on the eccentric is slow enough to keep a pretty smooth surface under the right conditions. We use no additional weight on the quill for figuring. The quill weighs in at about 24 ounces.

We actually have a counter-weight apparatus (not pictured) that reduces the quill weight for small laps. In place of a mirror we have a drawing that was drawn by one of our figuring machines. All machines have a signature pattern. It is good to be able to produce about 20 petals on an iteration, up to perhaps as many as 40, each taking roughly one and two minutes, respectively, before a pattern repeat begins. This particular pattern contains 19 petals, then the pattern repeats, offset from the first iteration, by 1/8 inch. This is ideal. A change in pattern overall (number of petals) is done by adjusting the ratio between overarm and table very slightly, while being kept between the parameters listed above. Once we get a pattern we like, we lock it in and leave the machine that way indefinitely. CZ

Figuring Preston's Mirror

Preston, This is where the rubber meets the road, and where it begins to get critical. Unknown: why a 60% diameter lap has the center overcorrected. Two possibilities, one, it was more overcorrected than that when you began to use the 7.5 inch lap, or two, contact is poor, such as the radius of the lap is shorter than the mirror. When the lap has a shorter radius, it will correct further in than typical, plus, the correction doesn't get out to the place where intended, which in this case is the edge zone. By appearance, the latter may be the case. In warm weather it is not uncommon for a lap to sag under its own weight after a short period of non-use, especially if the pitch is soft. (Soft pitch is good, but it also sags more easily.

Let's take a stab at this, and try something, going very slowly, a small bit at a time so as not to make things worse- Make sure the lap is well faceted so it will flow properly and cold press it for a long period of time, insuring perfect contact. After pressing you may need to re-facet yet again, then micro facet or brush. With a 60% diameter lap you should be able to do a full-length stroke with narrow offset, and both de-correct the center and correct the edge at the same time. I would try the following: after the lap is in perfect contact and ready for use, do slow, full length strokes with a two-inch overhang. Start with offset at 1/4", work for one minute. Change offset to 1/2”, work for one minute. Change to 3/4" and do same, and then to 1". Stop there, and go back to 1/4", repeat the process for a total of three iterations, which is twelve minutes of machine time.

This will not have a great effect, but should be quite measurable. We're doing this to see if it goes in the right direction. If it were a smaller lap, greater offset would be in order. Since it is a large lap, I can't have you offset a large distance because when everything is working properly it would flatten the center, correct the edge and produce a kink about two zones back. I'm of the opinion the lap may not have been right, so try what I have suggested. If it moves very slightly in the right direction we will do more of the same until the edge is almost fully corrected.

A 60% diameter lap should produce a smooth ML curve with greatest correction in the edge, sloping back to almost spherical in the center zone. If the edge doesn't start correcting, then we will employ greater offset, but that should not be necessary if all variables are in order. There are three reasons that correction doesn't get into the edge

(when all factors are in order), and they are all related.

It is either too small a lap, or too little offset, or two short of a stroke length. The remedy is to either go to a larger lap (which in this case we will not do as you are at maximum) or use more offset, which we might try after this iteration, or lengthen the stroke, which you also cannot do, as at 2 inches you are just about at maximum overhang which in an extreme case would be 28%. We never go further than 28% on a standard stroke, and usually we work at 25%. Give it a try and see if the center doesn't start coming up, and the edge begins to correct. (Perhaps you're having the same problem that Meade had with the 16). CZ

I have uploaded the current spreadsheet with the latest data set from this morning to try and see if I understand how to read the graph with the Wavefront Profile. After adjusting the "adjustment factor for COC" to 80, I can get all points in the graph to positive terms. Thus, does this in fact read that anything above the line is glass to be removed? A second question comes up, as I note that when the "adjustment factor of COC" is changed, that the percentage correction and general comments per correction do not reflect this change. Is this something that we may want or need in the spreadsheet being developed? Thanks for taking the time to look, Best Regards Preston ps. the last several sessions of 10-15 minute duration and 48 strokes per minute with a 3 rpm turntable and 7.5" lap per Carl's style. Offset was 0.25 to 1.0" from center, with a 1.75" overhang on both sided of mirror with tool. And of course your little thingy every so often Carl :<)

The entire mirror is under corrected from center to edge, and at the same time from zone one to zone two is overcorrected. This is simple to see in the percentage column. Also you can see it in the ML graph. If the plots go up from right to left the space between the two respective plots is overcorrected. If the plots go down from right to left the space between the two respective plots is under corrected.

If you want to follow our methodology do as John has suggested and type -301 into the box. That zeros the edge. The entire mirror is under corrected at this focus point. (Obviously, looking at the overall percentage, it is less than 100%). However from zone one to zone two is overcorrected. The large lap when used properly will de-correct that area. The way we look at the mirror is at -301 in the COC box. You have to remove 44 micro inches from the wavefront across the entire mirror, and that is what I'm instructing on how to do.

Now, if you want to ask specific questions as to details on how and why that lap and session layout works, that's something we could begin to address. Otherwise, that is how I would approach the session. The Figure bmp file is very large. It’s taking up a lot of space on the site and should be deleted when finished with it. I'm not going to address the image because it says the same thing our data says. It depends on where you set the focus. I'm going to teach from the spreadsheet. The lap sounds like slightly hard pitch. Its up to you if you use it, I suppose that at 80 degrees F it may be fine. If you want me to evaluate the lap an image of it would be a good thing. But I think you saw our laps and have a good idea. If you do upload an image perhaps you could use a jpg file, around

75K, then it can be deleted when we're done with it. Carl

Ok Carl, I understand what you have said, but before we get started I need to complete the little details.
1.) I uploaded into my file in the mirror makers Spreadsheet folder a screen shot from FigureXP...Please have a look as I am confused, to me that would look like a high under corrected center.
2.) The 7.5" lap is made from Acculap standard material and looks just like your laps. It is about .400-.500 inches thick and the facets are about 1" square. Even included the little 45-degree cuts on the face of the facets that alternate in different directions in every other row.
3.) I have been brushing the facets and then pressing in the morning for 30 minutes at about 80 degrees F and then brush and press 15 minutes if further work is done during the day before each session.
4.) We made a pitch tester like in Texereau's book that is a slight taper with a weight at the top. The Acculap standard tested about the same as Gugolz 64, but a slight bit harder.
5.) We have 64 and can make a new lap if you think it would be better. Regards, Preston
P.S., in the FigureXP our numbers in the KE readings are half as we are using a moving source. I just multiplied by 2 for your fixed source box spreadsheet.

I misstated below, the correct statement would be from "left" to "right", which is the same way we read. CZ

The entire mirror is under corrected from center to edge, and at the same time from zone one to zone two is overcorrected. This is simple to see in the percentage column. Also you can see it in the ML graph. If the plots go up from right to left the space between the two respective plots is overcorrected. If the plots go down from right to left the space between the two respective plots is under corrected.

Figuring Preston's Mirror (1st iteration in file folder)

Preston, Don't do another thing yet. Stop and measure again tomorrow, and do it carefully. What just happened is a train wreck. The mirror went totally out of control. There is something very wrong going on. It is not normal to de- correct zone six from 95% to 13% and correct zone 7 from 46% to 105% in twelve minutes, without even touching the center of the mirror! I have never seen such a thing. It would take us at least an hour to fully correct the edge zone from 46%, and the center of the mirror would have de-corrected by about half! What we're seeing appears like the effect one would have from figuring with a ring lap. -No contact in the center. You're having serious lap and/or technique problems, or possibly even measurement problems. It will be hard to tell precisely what is going on without seeing the situation. First thing I would do is pouring a new lap and make sure it is relatively soft pitch. Gugolz 64 might be okay at 80 degrees. Oh, and *before* you do that, upload a picture of the lap substrate. Get us some details on how it is constructed. It may be changing shape dramatically. I need to say something here for everyone's benefit. You can't build a machine and then learn mirror making. MACHINES DON'T MAKE MIRRORS, opticians do.

I made about 100 mirrors before I ever hit the switch on my first machine. I knew very well how to make superb mirrors before I employed the machines. I knew about pitch consistency, figuring technique, lap substrates, and a whole lot about all the variables that affect mirror making. Carl

Ok, I did a 1.5-hour press after brushing the facets. Lap is acting quite hard. Worked per instructions with offset starting at .25 then .5 then .75 and finally 1.0 and then start over at .25". Each offset movement was every 60 seconds. Ran 3 iterations for a total of 12 minutes. Tool overhanging mirror max 2.0" at 1.0" offset. Temperature in shop 80-degree F and 65%RH. The outer zones 6 & 7 are now in the ML window. There is only one data set in the spreadsheet because I added the two sets together to achieve the average and give me the multiple of 2 for moving source. Both sets of data were within .001" or better of each other. I will brush and press again tomorrow, running the same format as today unless instructed otherwise. It is SO nice to see something positive happening :<) Best Regards and Thank You Carl, Preston PS In folder iteration #1 is labeled JD12.5in29July04pm1455 i.e. size date and time --- In zambutomirrorgroup@yahoogroups.com

Preston, This is where the rubber meets the road, and where it begins to get critical. Dissertation on lap substrates (was: figuring Preston's mirror)

Preston, I would like to say I appreciate that you're willing to put your information and experience in the public and take all my flak that comes your way. Not everyone can do that. The value in this is *many* ATM's are watching this and learning tremendous amounts from your examples. It is very valuable, to watch what happens, both cause and result. I have never used wood laps. Ever. I used Plaster of Paris (long, sad story) and more successfully concrete product such as Pourstone anchoring cement, and Hydrocal. I understand dental plaster isn't so bad, either. I used concrete products until just after I began learning machine work.

Then I discovered... Metal. Metal, the wonder tool. Steel or aluminum, either is like taking a step up from amateurism to professionalism. Metal acts very stable. It is predictable. It doesn't cause any unusual errors that seem to come from nowhere, when pressed and used properly. Steel is rather heavy, and not too bad for polish. I also use it to figure sometimes when we have a lap that is just the right size and happens to be steel. In fact, the certificate photo is using steel. But now today, every lap we fabricate new is aluminum. The reason I don't like wood is because it springs. And I don't know that plywood will be any better than particleboard. Greg Furtman just went through a very long iteration of hard lessons (we're talking weeks) with a nice top quality (thick) multi-ply wood. Perhaps he would relate it to you if you ask him.

Here's my recommendation based on my experience for ATM's who spend the time, effort and money to build a machine. I recommend making the investment in a set of aluminum laps. Half-inch increments for diameter are good, and 1/4" increments although decadent perhaps, is even better. Once you use aluminum laps you will never go

back. The trouble you have just experienced will be out of the equation for good. If anyone is doing this and wants suggestions for thickness I can go through that for a particular diameter. Once we realized the value of metal for laps, we bought a slab of aluminum and found a machinist who worked for $50.00 an hour and had them cut out and turn a lot of laps for us. We have dozens of them in the shop now. For those who cannot afford to do this, I would recommend anchoring cement covered in resin, before I used wood. We did do a fair share of machine work with concrete product while we were making the transition to metals. The reason I recommend this is mirror making is difficult enough without adding total unpredictability to the equation. We need stable, predictable results when doing the work. A majority of the reason for ATM suffering is because of unpredictable results coming from things such as this that doesn't have to be so. We have our system down now such that if we want to remove one micro inch, we can do it. Not only can we decide how much, but for the most part we can also place it right where we want to. That kind of predictability is what is required to fabricate a superb mirror. CZ

Ok Carl... I need not upload a picture of the substrate...it was 3/4" particleboard sealed in Epoxy.... This is the first time using this substrate...typically, 3/4" Baltic birch ply... I said to our room mate, just after posting, that perhaps the lap was flexing and once the weight was removed...only touched the outer zones, Building an new lap like all of the others tomorrow with Baltic Birch 9 ply 3/4" and sealed in Epoxy... As I have said various times...I cannot see the difference in the knife edge difference visually...to within .015" We are using a ToUcam 740 to capture the image with K3CCD, and then looking at the gray levels of the image to determine the null point...We can do 5-10 series of measurements and come with .0005" of agreement...in each zone... I will say, that had the lap been G 64 at 1.5 hours press with 26.5 lbs. of weight...the facets would have been extruding from the edge!!! From past experience... We will have a new lap made and cast with G64 by tomorrow evening... Press and work on Saturday and Sunday... Thanks So MUCH, Preston

Figuring Preston's mirror (1st iteration re-measured)

Your discrepancy in measurements concerns me. I have a hard time accepting that the difference between 30 minutes and 12 hours should be that drastic. I'll set that aside for now. We wait at least one hour between sessions. Once the mirror is inside the ML envelope we wait longer, up to three hours as it approaches finish. Documenting is always done the following day. As thick as your glass is, you might wait a couple hours between sessions, anyway. Your second measurement is much closer to what I would have predicted. I was thinking yesterday after the "train wreck" that what we *should* have come up with in the edge zone was about 60%, and interestingly, you came up with precisely that. Note that your new figure is smoother overall. The center did come up a bit, which is what we also expected. The second zone from the edge de-corrected and put some out in the edge zone, which is also what we expected. These results are much better, and much more predictable, however at the same time, with soft pitch and a stable substrate I would expect to see the whole center, as in several zones, begin to de-correct together. Before you do another session let me know what you decide on lap substrate.

Then we'll think about planning another session. I do feel better about your second set of measurements. Group- would anyone out there be willing to attempt a 2-D drawing of the respective sphere, parabola, and where Preston's mirror is, given the way we are approaching the work? It doesn't have to be to scale, but if we have a side view (cutaway) of the glass surfaces represented by three lines (one line for each), then we can describe how the larger lap is working and what it does. It will be of great benefit to ATM's to begin to "see" what is actually going on. Most important are Preston's current surface and the parabola we are after.

Carl There is new measurements taken in folder after 12+ hours cooling. The surface is smooth and now there is about 37-38 micro inches to go vs. 44. The mirror is Pyrex at 2.372" thick at the edge. I normally have been waiting 30 minutes to take measurements. Perhaps this is not a long enough time for the mirror to reach equilibrium? What are your thoughts Carl? Best Regards, Preston

Cerium Pump

Our systems we use for dispensing polishing compound are essentially fail-safe, in that they have never missed. But you're going to pay about $450.00 for all the parts. A few photos will give you a rough idea, but without specific parts list and detailed instructions, it may not work out so well. If there is some serious interest in our dispensing system, whose core is a peristaltic pump and repeat-cycle time-delay relay; I will go through the effort to do it. They do provide very precise control, where you can control how much fluid dispenses per iteration, and how often it dispenses. But note also, it is only for one compound. In this case it would be polish. That's a lot of money for an automatic squirt. I'm just not sure you want to pay more for that than you did for your Mirror-o-Matic. If anyone else as well really wants to know about a dispensing system, say so. But I'll say this. For the first two years as a professional optician doing commercial mirrors, I squirted by hand. If I can do it for a couple hundred mirrors, an ATM can do it for a handful. Carl

Carl, would you be good enough to put some pictures of your cerium pump system in the photos section when you get a chance? (Or if anyone else has a system set up.) I've found an IV drip just doesn't cut it. Thank God belts slip.

Pyrex versus Plate Glass

Plate glass is fine in smaller sizes, but I think its 3x expansion over Pyrex may not be as good for larger mirrors. A well made 10" plate glass mirror is a fine thing, and 10 inch is a good size, but possibly the largest that I would consider in that substrate. And yes, good equilibration is important, but it is important for all glass types. Yes, it is said that the plate may finish smoother than Pyrex, but I don't know that it makes a lot of difference with good opticianry. The reason would be the grain of the glass itself, which means we're talking about angstrom surface roughness. I'm of the opinion that with right technique and polish compound one may be able to approach the single digit mark for

angstroms with Pyrex, so it may be largely moot. Also consider that plate glass breaks easier due to thermal shock. When fabricating, one needs to consider that. I have seen more than one porthole left in the sun crack right down the middle. That doesn't happen with Pyrex, as you know, because you can even put it in your oven, right? CZ

Hi Carl What's your experience with plate glass I observed through a friends 10 inch F8 circa 1970 which was manufactured by a craftsman that had a great reputation here in Melbourne at the time The images were first class, and even though the mirror took almost 3 hours to acclimatize to the night air, the mirror seemed first class. I star tested it and found textbook diffraction patterns either side of focus. I read somewhere that plate glass polished smoother than Pyrex, but obviously the trade off is the cool down time. If this is the case, why is Pyrex the preferred substrate? Carl I suppose my question is what is the real advantage of using Pyrex, if plate can polish smoother. Regards Con Stoitsis

Aluminum Lap Thickness Guidelines

Here are some general parameters for edge thickness for figuring laps. These are GENERAL only. They are not set in stone. I would say that there's a lot of room for variance in all directions, also I don't think all thicknesses listed are absolutely necessary. These are based on our laps in-house, and I'll mention here that they generally tend to be on the thicker side. If we had our ideal, we would send a few back to the shop and have them turned down slightly thinner. So following are our rough guidelines for aluminum laps:
3-3/4" diameter up through 4-3/4"- 1/2" thick
5" up through 6-1/2"- 5/8" thick
6-3/4" up through 8"- 3/4" thick
8-1/4" on up to approx. 12"- 1 inch thick CZ

Carl, I'm headed to the metal supply company for some .625" and .750" thick 6061-T6 aluminum plate. Will make laps with G64 about .500 thick in decreasing sizes starting at 7.5" and dropping in .25" steps to around 4" in diameter. Hope to have the 7.5 finished, poured, pressed and channeled by this evening. Thanks, Preston

Radius of Lap to Match Radius of Mirror an Important Factor?

For figuring laps (which are smaller than polishing laps) I don't think it is necessary. We don't radius any of our figuring laps, but do keep in mind that we typically use thick pours of very soft pitch.

We do however radius our polishing laps, especially when they get a lot larger such as 17 inches and up in diameter, and the sagittal causes a larger discrepancy. Generally I don't think it is absolutely necessary to radius a substrate under about 12" diameter. Carl

Carl, How important is it to have the 2 radii matching, thus keeping the pitch and even thickness? We have been doing this with the plywood laps by casting a filled epoxy to the proper radius in a plaster form having the radius of the mirror. If this is very important, I

will cast epoxy on the surface of the aluminum rather than machining the aluminum surface. Could you please discuss lap size verses thickness ratios? Or what are your recommendations. Thanks Preston

Grinding Tool

Grinding does not have the same tolerance as polish and figure. We also have grind tools made of Hydrocal and have found they are just fine. We do have steel and aluminum finish grind tools, but only because we can, and because it is convenient for production work. Such a tool lasts a very long time and we don't have to continually replace tiles. We do our rough grinding to acquire the right curve with Hydrocal or Pourstone, and tile. I don't feel it is necessary for the ATM to spend the money on (much larger) aluminum tools for grinding. CZ

O.K. This may be a silly question. All of my handwork has been with tools made out of HydroStone, a product similar to Dental Stone or HydroCal both of which Carl has mentioned, but cures harder and stiffer. When I grind, I use 1" square porcelain tiles, and when I polish I use Gugolz 64 making the tools following the steps outlined on my informational site www.johnstelescopes.com. My question. This topic of using aluminum for the polishing tool all makes sense but what about the grinding tool. Is it best to pour a HydroStone tool, or would some method with an aluminum plate be best? (BTW - I diamond curve generate ALL mirrors to within about .002" total sagittal before I start grinding, so the hogging out stage with a tile tool is skipped) John R. Zeigler

Not receiving a reply to my request for a drawing, (see again at end of message) I'm going to revisit the subject in greater detail. Is there anyone on the group who is monitoring this subject who understands the surface of Preston's mirror between his last two sessions (forgetting the 30 minute measurement)? Another way to say it is there anyone who understands where we're at and where we want to go, who would like to comment on it?

The next step is choosing a lap size. Is there anyone who understands why we chose the 7.5" lap based on the previous surface? Anyone care to venture where we go next? You see, given a particular surface I can tell someone precisely what to do and we'll probably get close if everything is working right. But I'm not sure that gives us the greatest learning potential. Until the optician understands *why* they did what they did, I'll just be giving you fish, rather than teaching you how. I know this is a lot of data all at once, but folks are doing sessions, and such activity requires full information. I don't know any other way than to just start inundating you with information and letting it begin to soak in (it takes time, but it does eventually soak in). That being the case, I would be interested to see some discussion about the shape of the mirror surface as determined by the data we have in front of us. John went into that area a bit recently, and did a nice job. Anyone else want to talk about it? What needs to happen in the end is the optician needs to be able to visualize in three dimensions the actual parabola itself. They need to see the lap in their mind and how it interacts with the non- spherical surface. They need to understand that a lap that is too large for a given area will flatten it back toward the sphere and at the same

time push the slope outward, depositing it at a particular place. This is the area we're embarking on now- the actual understanding of the surface of the glass, and of course, how to read the data in the spreadsheet, which is capable of telling us that precise shape.

That's why I'm asking for a drawing (or even an attempt at one). Yes, I could do it myself, but I do have some time constraints, and I think some group participation wouldn't hurt. CZ (previous message) Group- would anyone out there be willing to attempt a 2-D drawing of the respective sphere, parabola, and where Preston's mirror is, given the way we are approaching the work? It doesn't have to be to scale, but if we have a side view (cutaway) of the glass surfaces represented by three lines (one line for each), then we can describe how the larger lap is working and what it does. It will be of great benefit to ATM's to begin to "see" what is actually going on. Most important are Preston's current surface and the parabola we are after. Re: So what were we trying to do with Preston's last session?

I would think the drawing could be freehand. What I had in mind was simply a couple of curves showing the relative positions. That's what I meant by it not having to be to scale. It's a concept drawing, nothing more. It's not for the purpose of figuring, we already have that on the spreadsheet. The line for the parabola should be exaggerated and looks like a parabola, as opposed to the straight-line graphs we use on the spreadsheet. According to the way we do this, the outer edges of the two lines or, the edges of the shape you have now and the parabola you're going after, will be in contact (I'm speaking of the edge of the mirror). That is evidenced by that we zero the edge when looking at the shape, and stay in that relative position until the edge is almost done. From that point however, the lines as they progress toward center will deviate because you have glass to remove. The percentage correction column will have a clue on this concept drawing.

The wavefront graph with the edge zone zeroed out shows that the entire mirror needs to come down, and that is true. However when we look at the ML graph and the percentage correction, we see that the two center zones are overcorrected *with respect to the center portion of the mirror only, not the entire mirror*. Because of that we need to consider how to reduce the slope in that region while correcting further out. In a sense your mirror looks like a volcano. We have a hill that we need to remove, but at the top of the hill is a hole. Now the hole is still above where we want the finished surface to be, but if we keep the hole until the rest of the mirror is done, then you will have an overcorrected mirror. We want to take the ridges off the edge of the hole and flatten the top of your volcano, so that when we remove the whole thing, you'll have a mirror that is flat to the parabola. Seeing a 2-D line drawing of this will be of great benefit to the mirror maker, accelerating the process of visualizing how all this works.

Then after folks understand it in 2-D, it needs to be translated to three dimensions (preferably in the brain) so the optician clearly cognizes the paraboloidal shape and what they're trying to accomplish. CZ

I am working on the graph Carl...at least have the formula's correct I think. Once I get the difference between the sphere and parabola graphed, I think all one would do is to add

the micro inch deviations to the area at the outer radius of the zones...as seen in the wavefront profile to the perfect parabola's profile in order to see my current progressions. If I do not get it finished today, I will early tomorrow. I just finished machining the 7.5" aluminum lap...warming G64 as I type and will pour the lap .500" thick, then channel and warm press to shape this afternoon. I am sure that as I progress further toward the center of the mirror, we will be reducing the lap sizes as we move further inward. Hope that I can keep up in producing the required laps as we move inward. Regards, Preston

Difference Graph

Hi Carl, OK, I have a (maybe dumb) question about this graph (drawing). Maybe everybody but me understands this, but here goes anyway. If I take a 16-inch f/4.5 mirror (f=72 inches), it would seem natural to use a sphere of radius 144 and a parabola with focus 72 inches and the center of the sphere and parabola at the "origin". When I compare the sphere and the parabola, I find that the difference between them is 0 at the center and that at the edge the sphere is 180 micro inches above the parabola. But most of the difference is out at the edge of the mirror.

Yes, there is nothing wrong with that. It is a viable focus point and if you had a good method for smoothly removing glass from the edge back to the center you could certainly do so. But I think I already learned that this is a wrong-headed way to look at the problem. Only according to how we at ZOC figure mirrors. I hope everyone is clear on that. We REALLY don't want to work on the edge,

We want to work on the middle of the mirror. Well, at least I do. So...I choose a different parabola. Instead of a parabola with a 72-inch focal length, I shoot for a focal length of 71.89 inches. Now, the edge is where I want it, and my goal is to dig a nice smooth hole 170 micro inches deep in the middle of the spherical mirror, tapering it smoothly to the edge of the mirror. Yep. Now, if I haven't made a fool of myself so far, if you have, then we're both fools. Let's talk about the graph you want. On ANY scale that shows the curvature of the sphere and parabola, the difference between them is just too small to see.

Yes. That is why I suggested a conceptual drawing, not necessarily to scale. So...I could plot the DIFFERENCE between them. There are two ways to do that easily. The first is to plot the sphere as flat (by subtracting the sphere from the parabola). When we do that, we will see the "hole" we want to dig in the middle of the sphere and will track our progress by how far we have dug. The other way is to plot the parabola as flat (by subtracting the parabola from the sphere). When we do that, we will see the hill in the middle of the sphere that we want to grind down to get the parabola. We would track our progress by seeing how much we have reduced the hill. This way has the advantage (to me) that the goal is to flatten out the graph.

Need GRAPH IMAGE Here

Yes, the second approach is how we do it, conceptually. I uploaded a ***copy of the second approach to the futtrich folder in mirror makers' spreadsheet folder***. The graph shows

the hill Preston is trying to grind away and we can see that the top of the hill is getting flat...Preston needs to broaden the removal or there is going to be hole in the middle. Precisely. I just read your most recent posting, and I think I can actually do the graph you REALLY want, which will actually show the "volcano". Give me a few minutes and I'll post another graph. I just looked at it before you did your posting. You hit on something that I've been thinking about today as a teaching aid. I've always done that in my mind, but you've done it mathematically. I may be jumping the gun here, but I like the graph and am thinking about incorporating that very function into the main spreadsheet later on as time and organization permit.

I would like to tentatively bring the attention of the spreadsheet committee to what you have done and have them take a look at it. This could be rather valuable to the mirror maker. Well done! Spreadsheet committee, I'm standing by to hear what you think about this graph that Myron has put together. It could shortcut a lot of concept translation for the optician. I believe there is a mathematical difference in the wavefront profile and this setup, which I have not yet thought-through. Myron, since you created this thing, (and since you seem to be rather good at explaining concepts without math) would you be willing to give us a conceptual dissertation on the difference between this new graph and a standard wavefront profile? Perhaps you could help us to understand why this one shows this profile that more approximates how we need to see the mirror for figuring purposes. Amazing what can happen when a group puts their heads together on a common goal. CZ clear skies, Myron (futtrich)

How About a "Progress Graph"

Yes, yes, and yes. Everything below is correct as I see it. Oh, and I hope when you mentioned, "***grinding***" below, that you meant, "***polish***". (I'm sure you did.) Once again, superb now, I'm wondering if this can be incorporated into the main spreadsheet as a separate module, by creating a separate section for the formulas for the graph, as well as the graph. In other words, without disturbing the main spreadsheet, it would be added as an experimental section, where the formulas are off by themselves somewhere (although they draw off the existing document) for examination and further modification as needed.

I'm thinking that the COC constant function should apply here as it does everywhere else, because we will not always zero out the edge perfectly. Also, (and this is a simple thing) I think it would be safe to draw lines between the plots, as this is an actual surface as relates to a particular perspective, unlike the ML graph. If you wish to, I would be interested in your formulas used in the creation of this, if it exists as an Excel file. You could send them offline. I'll leave it up to the committee otherwise to correspond with you on this, as I'm not involved in their everyday discussions and development. Right now I don't know where they are at, and its up to them as to how this will be handled. CZ

Carl, I think I have an idea how to present the information that you wanted in the drawing. Best of all, it shows the "volcano" that you mentioned. When we look at the mirror in a way that puts the edge in the right place, we see that we have a "hill" in the middle of the mirror that needs to be removed. When we look at how much of the "hill" Preston has removed, we see that he has cut the "middle" of the hill down faster than the

sides of the hill. So...we can look at the percentage of the hill that remains at each radius, we get a clear picture of how well the polishing is going. The "percentage remaining" graph tells us that Preston is digging too fast in the middle of the hill. I have uploaded a copy of a "percentage remaining" graph for Preston's mirror in the file "Preston percent remaining" in the "futtrich data" folder in the mirror makers' spreadsheet folder. Clear skies Myron (futtrich)

I need to make a disclaimer this weekend, as I'm much more tired than normal. This last week was unusually taxing and when I saw Myron's percent correction graph somehow I made the mistake of seeing "surface". It isn't necessarily so. It is a percent correction graph. This is not to take away from the work that has been done because it is good work, and I'm hoping that somehow we can use it. I need to slow down and take some time to think this one through. Other comments are obviously welcome. I think what happened is when I saw a graphical representation of what I was trying to get across conceptually I made a leap, and made it too fast. Perhaps the dust needs to settle a bit. I think Myron did come up with some good stuff and I think it's worth discussing. My question would be what is the connection with the surface we're trying to describe and Myron's "volcano" graph. I need a vacation. CZ

Hi everyone I've been taking a much-needed rest. As I feared, the discussion is moving at record speed, there is so much happening so fast. I don't have the time to answer every specific question; so if you need it again, do ask again. I'm going to try to keep up with everyone, and I'll do a short recap as well as give you some more information.

Myron's percent difference graph is the concept I was after. What Preston needs to work on is the hump between the center and the edge, but at the same time take the entire mirror down with respect to the edge. Another way to say it that has already been very well put is he needs to do less glass removal in the center relative to the rest of the mirror. John did an incredible job of analyzing a prospective technique, which I must admit made my eyes glaze over, but I think he essentially got it right. Preston is correct in what I'll recommend next, which is, more of same, given that his last measurement is reasonably accurate (repeatable is what I mean).

Now, here is why, and the next block of information- the reason we use different size laps for the method we're employing is we're creating an aspheric, or, non-spherical shape. The lap will generally tend toward always being spherical as we move it around the mirror. The slope in the glass that we're attempting for a given aspheric (parabola) will be different from the sphere that the lap wants to stay at. Softer pitch does better at sinking in and staying with the parabola, and of course harder pitch does worse. There is a balance point that each optician must find over time to be comfortable with. But back to the subject-

The faster the mirror is or the more slope it has, the more deviation between the shape of the parabola (non- spherical) and the shape of the lap (spherical). We have learned through experience that 60% diameter lap is a rough average size for correcting a particular radius of medium focal ratio. That is, if we want to correct a 10" radius at F5 to

F6 (for that radius), or, the edge zone of a 10" mirror at same F/ratio, then a 6" lap is generally a good size to do that.

Now here is what happens- this 6" example lap will cause everything inside of the 10" radius to generally move back toward the sphere. This effect is minor just inside or near the 10" radius, and increases exponentially the further in we go, until it is essentially spherical at the center. But this effect is also widely variable. The variables are F/ratio and pitch hardness.

For example a small F/8 mirror can probably be figured with one lap, because the sphere and parabola are so close together. But change the F-ratio to F/4 and you need more laps of different sizes, because the one lap won't correct down in toward the center any more, because the slope is steeper which causes a greater deviation between the shape of the mirror and the shape of the lap. The 60% diameter lap on the faster mirror will tend to wipe the slope from the center (or, it won't create it there in the first place) causing it to become more spherical, and deposit that slope further out.

That's what we're going to do with Preston's mirror. So let's look at Preston's percent difference graph and think about what we're going to do. We need correction in the edge, it is our most under corrected zone, and we want to finish the edge essentially first, with a smooth progression of de-correction from one zone to the next going inward. What I mean is, a nice progression at this point instead of 123% in the center and 60% in the edge which it is now, would instead be, in the edge something like 97%, and 50% in the center with a smooth percentage change in-between

So a 60% diameter lap will correct the radius it is ideal for, and correct less and less further in until we have almost a sphere in the middle. That is a general trend. So can we apply that to Preston's mirror? Yes, we can. Now when Preston presses his lap he is going to press an imprint of the volcano in it. BUT, he is going to stroke that imprint with an overhang of two inches on each side that is going to begin to wear down the edge of his volcano. (The lap will also move back toward a sphere as he begins moving it) Harder pitch will wear the edges of the volcano more, and softer pitch will wear it less. I'm going to go for 64 Gugolz as a happy medium and see what happens. In Preston's shop it will be a bit soft, so I don't know how much the center will de-correct, but I do know it will have some effect. So we will do a stroke that is designed to correct the edge because it needs it. What we are hoping for is that this 60% diameter lap will *at the same time* decrease the center zone slope, because it is going to flatten the mirror back toward the sphere, more toward the center, and less and less toward the edge.

If we didn't have a large lap and had to use a smaller one, we would simply use offset to do the same thing (make the lap behave as if it were larger). We would set the offset so it works hard on the 50% to 70% zone, which would again, correct the edge, and decrease the slope in the center. So Preston, here is what I recommend, if you're willing to again risk your work. Given all the variables most of us understand exist in this work I can't make any absolute guarantees, but if I were looking at your graph on my computer and had the mirror in front of me, I would do the following-

Repeat the same process, but this time we will spend more time on it, and lose the outermost offset position. With 7.5" lap and a 2" stroke overhang, we will do one minute in each of three positions, those being 1/4", 1/2" and 3/4". Do it six times for a total of 18 minutes. There are three reasons for approaching this slowly:
1, I don't have control of all your variables, so I don't want to go too far at once.
2, we all get to see this progression in smaller steps, so there is more information.
3, if we start veering off course we won't go so far as that we might not recover.

I'm eliminating the outermost offset position (1") because a 60% diameter lap can be very effective at correcting the outer zone, and if we offset too much at some point you'll have something more like the first set of measurements with the overcorrected edge and the under corrected zone 6.

One more thing, the effect of spending one minute in each position and moving outward each time, then starting back at center and moving outward in each three minute iteration is also designed to help de-correct the center. As you go outward with the offset the correction that the lap is effecting overall moves along with it, equal to the amount you offset, and have an effect in each respective position equal to the time spent. Another way to say it is, the general trend toward the sphere in the center that the lap creates will push correction outward, instead of the other way.

I would wait some three hours at least, before measuring. The next day may be even better. CZ

Stroke, Offset and Lap Size

There is a lot going on there, which is difficult for me to explain, but I'll do my best. With a 60% diameter lap the overall general trend is for slope from all zones to be pushed outward and deposited in the edge. So in general all zones except the edge will de-correct slightly. Because of variable conditions and measurement error, you may not see this precisely in every zone every time, but the general overall trend is there. We will witness this as we move along. If we go slowly, it will give us many iterations like a moving picture, and a very important effect will be catalogued for all time. We can afford to do this lap size and stroke at this time, because the edge zone is only 60% corrected. It has a long way to go.

Part of the reason I just recommend that Preston eliminate the outermost offset position is because of that de-correction from zone five to six. Its pushing out pretty hard into the edge zone, and I want to slow that a bit. At the same time, I want to be able to de-correct the center, so I'm striking a balance point. If I were just putting in new, fresh correction I would probably spend nine minutes at 1/4", four minutes at 1/2" and two minutes at 3/4". That would be a nice balance for putting in new correction. So I have to watch the offset. More of it will transfer slope from zone 5 which you have referred to, into the edge, and at the same time less of it won't remove as much slope from the center. But I agree with you, overall the general effect of the session was everything going toward where it needs to go. What the group may not understand yet is what a 60% diameter lap does overall. If

we have enough correction to do in the edge we may catch a glimpse of it before we leave the 7.5" lap, which is less correction in each zone from edge to center.

Under normal conditions at the finish of the use of the 7.5" lap we would have full correction in the edge, and less and less as we go inward, with the plots moving higher in the ML graph more and more one after another, toward the center. Yes, it is complicated stuff. That is the price we pay for (ultimately) having very precise control. CZ

Hi, Comparing on the charts mirror data before and after Preston´s action, all zones except 5 are going to their correct desired positions. Some more times this same correction spell may bring profile near the low error careful areas! I used -301 (before) and -254 (after) COC adjustments to keep edge constant at ML and RTA charts, for comparison. If Preston really goes again with the 7.5" tool and we can see if the behavior repeats. What I can´t understand is if zone 5 not moving has some relation with the tool size and stroke. Ricardo Dunna

Preston, on further consideration I'd like to back off a bit on your next session. I'm looking at the relative shift in percentages from zone 5 to 6, and 6 to 7 in the last session. It's pretty strong. If we move the same amount in each respective zone in the next session we'll have 71% from zone five to six, and 74% from zone six to seven. This will be the first time you have more correction in the edge zone than the one inside of it and that is fine, but we're complicated by the center being overcorrected.

Once the edge zone is stronger than the one inside of it we may need to leave the larger lap, which limits our ability to de-correct the center with strokes near center offset. I want to use the large lap as long as possible. If you don't mind doing more iterations overall and watching this progression slowly evolve, I would like to suggest reducing the session back to the same amount of time as the first one, twelve minutes. We'll do the same time, but have slightly less offset. If that's okay with you, let's go very slowly with this project. There is a lot to see and learn here, and I think it's worthwhile. Carl

Preston's Next Session (Reconsideration)

I'm on board Carl, I will finish pressing in the morning the 7.5" aluminum backed lap with G64 .70" thick...in your method... You mean the pitch is .7 inch thick? That's quite a lot. It will probably be okay; at the same time we don't usually use any more than .5 at max for a figuring lap. Then I will do a couple of sessions of 12 minutes...with measurements between each...to see if we are going forward??? I'm suggesting a total of twelve minutes for the entire session. I'm hoping to see the mirror move slowly in the direction we want. Offset to be only .25" to .75" Four sessions of 3 minutes each, for a 12-minute iteration... Yes. Carl

Finally measured my Galaxy 18 mirror

Myron, I failed to mention recently that we don't mention the names of individual mirror makers when referring to optics analyzed on this forum. Fortunate for us you have a good

mirror with a good test. It should be an excellent performer, as you already know.

Hi folks, I just finished measuring the Galaxy 18 from my Tectron scope. I uploaded Carl's 7-zone spreadsheet for this mirror to the "futtrich data" folder in the mirror makers' spreadsheet folder. This mirror is better overall than my Meade 16. I can live with a Strehl of 0.95 although the RTA and M-L could be better. They ARE better.

The zero in the COC box is a focus point chosen by the spreadsheet based on balancing the total error in all the zones. That doesn't mean you have to focus the mirror at that point, and at the eyepiece you probably won't in this case. So change focus by typing the number "15" into the COC box. You'll see that the Strehl remains the same, but the RTA and wavefront both improve. And if you type in a "10", you maximize the Strehl rating to .957 and improve the RTA to .98, as well as have better than 1/10 wave to boot. Looks pretty darn good to me. This mirror tests VERY well at the eyepiece so I am prepared to believe that the KE measurements are close to right. There are a LOT of heat waves in my garage tonight and measuring the 1st and 7th zones is hard. I'll try again tomorrow AM hopefully before the heat waves get started. I don't believe that this mirror is as smooth as the Meade. I think I can see some small-scale features in the KE test. These features are arcs of ever-so-slightly different contrast and there are a couple of them. They don't seem to be continuous rings, but the KE test is 1-dimensional so I'm not sure if the fact that they don't seem to go all the way around means anything. These "arcs" are REALLY hard to see and with all the heat waves. I am not sure that they are really there, but they do seem to persist, reappearing during moments of quiet air. Please keep in mind that the knifedge test allows us to see surface errors as small as 1/600 wave according to Texereau. It is EXTREMELY sensitive to the eye on the surface, comparably speaking. I would not be too concerned with surface anomalies that are so small as that they are on the threshold of detection. So, my "perfect" mirror is perfect no more, but the results are consistent with what I see at the eyepiece, and I like what I see at the eyepiece so I don't plan to worry about it (at least not tonight). There are no perfect mirrors. Nevertheless, from your description of your test and your measurements I would say you have a rather good one. I expect you should be very happy with it. CZ

Figuring discussions (are we moving fast right now, or what?)

At this point, I am trying to figure out WHY a particular size lap does the work it does. Instead of learning a series of techniques, I want to know why it does what it does so I can adjust my technique depending on the entire surface of the mirror. John R. Zeigler

You're not an analyst, are you, John? :) There are so many factors involved that I'm not able to tell you precisely "why" in a full body of teaching. I learned from empirical results. I did "this", and "that" was the result. After thousands of iterations I've come up with a body of technique, probably suited to every imaginable combination. I look at a surface plot and immediately my mind says to do such-and-such. I'll take a stab at giving you a lead in a direction, from which place you will likely tread on your own. In a CAD program, or on paper, (or in your mind if you wish) draw two circles, one representing the mirror and one representing a sub diameter lap. Consider that the 80% zone of the lap

very roughly is the balance point, inside of which things move toward spherical, and outside of which correction is deposited. Now, stroke the lap across the mirror any length you wish, and see that swath in an arc across the mirror. Now, spin the mirror, setting up the relationship between table and stroke speeds, and see the relative action spread out radially in varying proportions. Now, add some periodic offset to prevent zoning on the side of the swath. Then, factor in F/ratio and relative slope between the glass and the lap, which is a variable in how much action stays in a position or moves outward. Then also factor in pitch hardness, because it is another major factor in where correction is deposited in the process of a stroke. All those factors are working together, at the same time, all the time, and there are others as well, of lesser effect.

The best I know to do is wish you luck in designing techniques through analysis alone, because if you are able to do that you've left me in the dust and will be in another league. I suspect you can get a starting point, but I have my doubts that one is able to predict precisely what one wants to do through just analysis and the "why" of it, without rather extensive experience. It took me years to get to where we're at now. I'm a better paraboloid optician today than I was one year ago, and I can point to the differences. That was all after 1,000 mirrors, BUT there is a saving grace in all of this. It is what I call "measure and adjust". What any mirror maker does is execute a session, then measure. Then, based on (empirical) results they make an adjustment. If we do a little at a time, and consider theory *based on what we have seen* rather than what we think may be in the future, then we should have a chance at moving in the right direction. Disclaimer- everything I have said above is based solely on my personal experiences. You may have insight that I don't imagine could exist and if that is the case, that's a wonderful thing. Carl

John, I'm very happy that you're on board with us. I think you bring above-average experience with you that show through plain and clear when you correspond. What I notice about folks with experience is we usually seem to speak the same language. I've mentioned this concept before, regarding Bob Goff for one example. Listening to yourself it shows through to me, as you understood very clearly what the spreadsheet is doing, and how it works. I think it takes some experience to be able to see this thing that plainly. I enjoy your postings.

Carl No, I am not an analyst. I just have not had the time between my full time job and having students by the shop nearly every day to get my machine finished. It is SO CLOSE though. The reason I am trying to figure out why the laps work the way they do is to gain a foundation to start machine figuring on. Once I start the figure - test - figure process, I too will start gaining that experience that tells me ... With this surface, I need to do this ... You have a lot more mirrors under your belt than I do, probably 10 - 20 times or more. I am at a point where I am striving to go up to the next level of quality and performance. I have made some excellent mirrors, but I know that I can do better. I am always setting my own benchmarks and working to reach them. Then I set a new benchmark. I can see a lot of areas where I have a lot to learn. I am grateful that you are willing to impart your experience to those of us who are willing to learn. Thank You. John R. Zeigler

Commercial Mirror and Tests

At ZOC we support the concept and practice of amateur astronomers becoming informed by all applicable means. As I've mentioned before, part of the reason behind our former documentation was for those who use the knifedge test to replicate our measurements, or if they simply wanted to get anyone to measure their mirror they could take it to them along with the paperwork and see how it comes out. I should apologize to those who are still at this forum expecting the original charter to be in full practice. At present, the forum for the most part has migrated toward mirror making. Perhaps we said and did just about everything we could concerning Zambuto mirrors in the first two years of discussions, without actually getting into how they are fabricated, which we now are essentially doing. At the same time the archives are still a valuable resource to anyone who wants to explore them. I don't mean for the mirror group to become just a mirror maker's forum. All aspects of our former discussions are still encouraged. At the same time, apparently a service is being provided, because folks are here and interested, and participating. So for the time being that's okay with me. Back to becoming informed- I don't mind at all when an astronomer who is a non mirror-maker wants to test their mirror on the bench. The more tests they have that are in agreement the better, I think.

One result of doing this is commercial mirror makers can't pull the wool over their eyes any longer. That has been done in the past. Furthermore I know for fact that information that has gone out through our efforts has effected major changes in the quality of product available to the amateur astronomer. And I believe a significant part of that has been our effort to educate in test methods, much of which has been discussed on this forum. Wouldn't it be something if commercial mirror maker's didn't need to supply documentation to their customers (or perhaps that it didn't matter whether or not they did) because the customer is informed enough to know what is good and what is not... CZ

Hi Con, Actually, it is my beginners fascination with being able to make the measurements at all. My KE tester has existed for only a week or so. However, I have learned a lot and being able to finally measure the mirrors has helped me in two ways.
1. The first mirror has always been a marginal performer. I knew that the problem had something to do with the edge, but was a little surprised to find out that the edge was HIGH. In any case, the middle 14 inches of that 16-inch mirror are VERY good (very smooth and well figured). I will simply mask it off for the time being and use it as is, in my backyard as a drag-and-go scope.
2. The second has always pleased me at the eyepiece and star test very well. I was pleased to find out that the views and star tests were confirmed by the KE measurements. It was just a check on how well I could tell what was a good mirror. Ultimately maybe I'll actually make a mirror and then the experience with the KE and the various analysis tools will finally pay off. Clear skies, Myron

Hi Myron In relation to your mirror, I know 3 people who have had their mirrors professionally tested. The mirrors were from companies who have outstanding reputations, and the results were good, without being outstanding, as promised. Having said this, if your scopes are performers in the field, why would you bother testing them A

friend of mine has this obsession with testing his optics, even though I have viewed through his 10 inch F6 scope many times, and have found it a very good performer. It star tests very well, and its performance is right up there with my Zambuto equipped scope. I say to him regularly, why bother People become obsessed with figures, instead of performance I'm glad Carl no longer supplies stats on his certificate, as people seem to read the results only, and not the information on how these figures were obtained.

Ignorance on the whole process, is breeding doubters, it is all about performance, nothing else Enjoy your scope, as much as you can Regards Con Stoitsis Melbourne Australia

KE Foucault testing with CCD camera and source of possible errors

Mike, thanks for taking over on this one, I appreciate the relief. All appears to be on target from what I see. Please do carry on. I'll concentrate on figuring when Preston or anyone else is ready. Carl

Hi Mike, At this point I'm open to discussions.
1.) I think that I now understand why Carl is using a fixed source. It has double the sensitivity of a moving Source. I don't believe this is true, having used both types. They should have the same sensitivity, assuming the tester is properly set up, the operator is experienced, and the motion of the knife-edge is accurately measured. I was assuming that if with a moving source the total travel is .202" and a fixed source light is .404 or double, then the readability is twice as sensitive. Perhaps I'm misunderstanding something. I am also assuming there is no slop in the micro stage, and that nothing in the test setup is moving (including the floor, test stand, etc.) Finally, air currents will always make readings unreliable, so I assume everything is at thermal equilibrium. No slop, no air currents, mirror cooled 12 hours, DRO scale attached to micro stage in .0001" calibrated digital Mitutoyo. Assuming none of the above is contributing to the problem, it might be useful to see a photo of your tester, to see what type of light source you have and how it is arranged. If you have already posted these details, I have missed them and I apologize.

The tester is a modified William Bell and if pictures will help, I'll post them tomorrow. Regards, Preston

Carl, How do YOU use the 7 zone spreadsheet

In the case of Preston's measurements, if I understand correctly, the lap that you were recommending should tend to flatten the M-L diagram for the first four zones in the middle, moving the peak of the M-L out toward zones 5 and 6. I hope that is a correct interpretation.

Yes. And as Preston and Mike are both well aware, we can't do anything until we have verifiable, repeatable measurements. My mentor once said to me, "What you cannot measure, you cannot control". Anyway, after working with the spreadsheet, I have a question. When you are figuring a mirror, do you pick a new COC adjustment for each

set of measurements or do you use the same COC for all measurement sets? Now there is a good question. If anyone is paying attention to underlying trends, sooner or later somebody is going to figure out something rather interesting. I wonder if anyone has noticed that the only aspect we have been talking about with respect to Preston's mirror (for example) is "percentages of correction". What does that imply? That implies M-L. (Bob M., this is one of your "hidden secrets in plain sight"). Yes, we figure off the ML information until the outer one, two, or three zones are coming in for a landing. We look only at percentages of correction until then.

That is why we had this big "to-do" about the volcano. If you look at the ML graph on Preston's mirror with the edge zone zeroed out you'll see half of it (surprise!). Now once again, that is NOT the surface of the mirror, but what it does is, as long as the mirror is under corrected and the outer zone has a ways to go and the outer zone is zeroed out, is does provide a profile with a particular type of information to work from. This information is best described in the discussion we had about how to figure in light of the shape of the volcano we all observed. I think it was covered pretty well.

So, to answer your question, it goes like this:
1. We look only at percentages of correction and the ML graph for quite a while, which means we adjust nothing with respect to the COC. We let it float at wherever the spreadsheet averages it because the relationship between the zones is always the same (percentages from one zone to the next) no matter where the graph sits with respect to the envelope. If you want to zero the edge zone out after each session that is fine, but it isn't terribly necessary.
2. Once the outer zones begin to get close and we need to *precisely place correction* (we have not done this as yet on the forum), then we adjust the COC to zero out a particular zone and we move our attention to the *wavefront graph* which tells us where the correction will be placed. Each session will require a different COC constant, because the hill that remains changes shape every time. We will demonstrate this when the time and examples come our way. That's how we use it, and of course there are many examples to come. Carl clear skies, Myron

Preston's testing

Preston, One of the problems with diffraction may be simply that there are too many zones for your personal (optical) comfort. At one time with 12.5" mirrors at F/5 we went back to six zones from seven and found them easier to read for a while. We have now returned to seven zones at present, especially with F/4.5, but we could do it either way. I hope our one spreadsheet having only seven zones is not causing all of this trouble. My first recommendation would have been to fabricate a mask with six zones and try it to see how you like it. The point is to get repeatable readings. If we have to, until the committee generates some other zoned spreadsheets we can use other data reduction, or I can upload graphs and information from reading sets.

About the tester- we use a potentiometer on white light, which is a 20-watt halogen bulb. We really do prefer white light. We use the variable aspect continually, from zone to

zone. I use brighter toward the center and dimmer toward the edge. This helps tremendously in working with the diffraction effect of the Couder mask, especially out at the edge. I often have the light so dim at the edge that someone might think I'm doing something wrong, but I find I can detect very well at low levels, and the diffraction is noticeably reduced. Also, the width of the slit is a factor in contrast. Our typical opening is about the thickness of one sheet of 20# paper, which I recall may be 30 microns.

The next item is to test in the AM, first thing in the day when it is quiet, the place is cool and you're feeling fresh. Nothing seems to help more than that. An item that may be overlooked is the optical quality of one's eye. We find it important to have a top quality current prescription in place for any corrective lenses. I'm nearsighted, which means I need correction for distance. I use a large lens bifocal specifically for testing. The lower element has zero power because I'm nearsighted so much so that I can read the micrometer clearly at 6 to 7 inches with no correction. (I'm sure doing that exercise over the years has helped in that.) What I didn't realize was that reading at that proximity through a distance-correcting lens was making my eyes worse, causing me to need more distance correction. Once my eye doctor (who is top-shelf, btw) pointed this out, we fixed the problem by getting me bifocals. Now I look through the lower portion at the micrometer with ease. But the point here is my distance vision is corrected to 20-15. I can read anything and everything on the chart with the possible exception of specific letters at the very bottom, which have a middle line in them such as an F or an E, and then I say, "It has to be one of three letters..."

There are also techniques for minimizing stress to your eye while testing, which we can discuss briefly if you have any interest. Eye fatigue is certainly a factor, and is worth considering. Testing is an art form. It’s not necessarily easy, and the older we get the more work it is because it requires large amounts of energy due to concentration. But we still do it the old fashioned way, because at present we don't have a (fully calibrated) system that can repeat to better than .001 on a fixed source tester in place and operational. Perhaps one day we will if it is somehow possible, and then again, perhaps not.

I'm concerned that you solve this testing problem. Let us know how it goes. Carl Hello Mike, I am going full force in testing and varying the variables...I have learned a lot about pin sticks today...I will follow up tomorrow... I'd encourage you to keep testing on your own in the meantime, and see if the practice helps. When things are going right, you should get repeatable numbers no matter what the state of the figure of the mirror. (When my numbers are not consistent, I know that I'm either too tired, there are air currents, or I've had too much beer!) One of the reasons that I took to the CCD and imaging is that it was just TOO stressful to try to do it visually...and this is in the morning...I tend to take to a good red Wine in the evening...no testing after wine :<)

What type of light source are you using? Is the tester slit less? Yes it is at this time. I may look back to the slit as James’s recommended from his Robo Foucault testing...But I have used all 3 types. What is the light source? LED? Flashlight bulb? How bright is it? (I use an extra bright blue LED - the color is very easy to look at for a while.) I have used Bright Green LED's, and flashlight bulbs. Controlling the brightness with a variable

potentiometer. I just want to get back to a point that I trust the numbers generated to feel safe on using them for the data reduction... We are in figuring withdrawal.....and missing Carl's smiling face.... :<) Hope to have a solution by the end of this coming weekend... Best Regards, Preston

Preston's testing

I hope that what you're doing is because you enjoy it, which includes the satisfaction of making strides in a new hobby, because it is not cost effective given all that you're going through. Buying a Zambuto-equipped scope should be considerably less in time and cost :) What you're going through, Preston is not unusual nor are you alone in this. Opticians who have ever done good work had to pay their dues. There are so many variables and nuances it is not imaginable for the uninitiated. There is no way for the inexperienced to dream up all that an optician must go through to get to the place where they can make a superb mirror. We spent years just ironing out variables, one at a time. The beginner will be faced with all of it at once if they are to fabricate relatively good mirrors. It does require tenacity and determination to succeed. Again, I hope you truly do enjoy the process. ...And keep listening to Mike. He's got good experience and a broad perspective. Carl PS perhaps one day I'll tell a story about my most aggravating experience, very early in my mirror making days.

It is down to either get a test that works for me OR buy something with Zambuto optics...and I have devoted so much time and energy to this in the past year it would be such a waste to not follow through to the ending, what ever that may be. Thanks Again, Preston back to working on a solution.

I've uploaded the 7-zone spreadsheet with a complete history file of measurements on one of our mirrors. It's in the files section, in the Mirror Maker's Spreadsheet folder under ZOC generated files. It is called 12.5 7-zone figuring progression. This is not a document about how we figure the mirror, but rather about how we use the spreadsheet from start to finish when fabricating an optic. Under the main working section are eleven sets of measurements, which are the actual history of the mirror. Be sure to see the general figuring comments just above that section first. What you do is copy and paste each successive set of measurements starting with set one, then read the comments in each box for each set. This is essentially an ideal progression, so not only will you see how we use the spreadsheet here in the shop, but will see the figure of the mirror evolve very much like we like to see it go, from a rough parabola to a finished piece. This is it, folks. This is how we do it! CZ

How we use the spreadsheet- real world figuring progression

Yes, jump-starting was my intention. I noticed the struggles going on in every quarter and wanted to open the door to provide a glimpse of how it happens "on the other side". The mountain is steep; the path is long and narrow. Obviously, it is not easy. But sometimes it helps to see a slalom skier turn each pin on the downhill perfectly and with ease, first to believe that it is actually possible, and second, to get us revved up to want to go out just

one more time and try the next step. CZ

You have just added more vigor to my determination...but you knew that this display would really get me jump started :<) Thanks So Much, I needed that!!!!!!!!! Best Regards, Preston

Production cost - North America vs. Overseas

I *wish* I was going; it would be great to meet you, Scott. Thanks for your story, I understand and appreciate it. This is another subject and off topic, but my (rhetorical) question on the story would be what kind of calibration must be required to get an interferometer to justifiably claim 1/20 at Peak to Valley? I can understand such a number for spherical, but every point on the surface, that's quite a claim, and, quite a mirror! Holy Moly.

Carl About 12 years ago I was working for a small firm that sells precision optics to the Military industrial complex. <Snip anybody on this list going to Stellafane? Scott Milligan

Real world figuring progression (Preston's slit less Foucault testing)

Without telling you how to do your testing I do have hopes that along with everything else you're doing, at some point you learn to apply some method for straight visual testing. Every professional I know who used and uses the knifedge does so visually. We understand how many variables can come into play and compound each time any other optical component is added. A phrase that has stayed in my mind over the years from a mentor is, "I have NOTHING between the surface of the glass and my eye". Doing so keeps everything very simple. The slit is simple as no machining or high level adjustment process is required, and the tester is simple. In the end I think an advanced mirror maker should have the ability to measure accurately by eye. Carl

Hello Everyone, No I am not sleeping nor have I given up...Not after Carl's Jump Start...I am more determined than ever...I can and Will figure a Way!!! Without doing so visually..... So what did I find out with the slit less Foucault...Very nice, but I am unable to remove the knife edge from the light path return to be able to adjust the gradient to even... Very nice images, but they will not work with Carl's data needed for the spreadsheet. So on to a very fine slit...machined both sides today and lapped the knife-edges...the previous version was just not up to our standards... I will work tomorrow to attach the moving blade and mount the new source...no more batteries...variable output DC voltage and amperage...Really nice :<) Will it work? I really do not know...with the CCD but James recommended a very narrow slit for CCD work, so we are building a slit that should be adjustable to .00005" increments...We shall see??? Very Best Regards, Preston...

I started this as a tangent issue on Preston's posting, but decided it should be its own "thread". I wish to say again for the benefit of the group: A major key to our success is

not complicating anything that we don't absolutely have to. I get the sense that many folks were underwhelmed by the presentation of how we use the spreadsheet. (I haven't seen one question as yet). Sometimes the "truth" is the very most simple. That's often hard to accept when we're looking for fireworks to go off. -No fireworks here. The beauty of what was presented is so obvious and simple that many may have missed it... Please note that the mirror that was done in that presentation has its greatest error at less than one thousandth of an inch on a moving source knifedge. That means no zone on the mirror deviates more than .001 from the parabola with a moving source! And furthermore, the mean deviation is .0003! How many mirror makers amateur or professional produce a fast 12.5" mirror that measures to less than plus and minus .001? Does anyone else do that? And how is that done? It is done through precise placement of correction, which is possible because of the method that was presented. I think the core message of what is really going on in that presentation was missed by many.

Another way to say it is, I'm not sure every mirror maker who is interested in this information "saw" what he or she were seeing. There's a diamond sitting in front of everyone, for those who have the ability to see it. I think perhaps some folks may be looking for "pop and fizz". Well, sorry to disappoint. The pop and fizz is an extraordinary optic, which was produced through a straightforward method that was developed independently over a period of years, through nothing more than experience, which method is now public.

There are no other "secrets". It’s all right in front of everybody, right now. There is no other "big deal" that's going to come out of this. I've already explained the basics for choosing lap sizes and how to apply it to the work. I've already discussed and given examples of how to keep things in motion to avoid zoning, and to blend one radius into the next. I've already discussed general parameters for pitch hardness and which way soft and hard pitch goes. In short, the core instructions have already been given out for essentially the entire process. The last part was a sample progression of how to use the spreadsheet.

The only thing remaining is experience; beside myself actually instructing one figuring session after another for specific examples. You all have more information right now than I ever had. Nobody gave me software with an explanation of how and where to specifically apply correction. Nobody told me precisely what a figuring machine should be able to do, let alone give me an actual photo of a machine-top layout. Nobody showed me any figuring progression, from start to finish and how to do that. Nobody told me what size lap to use with respect to a given radius, and generally how it would act. Nobody told me how soft and hard pitch would behave as a trend on the parabola. All of the above has been given to you, and other than Preston being charged-up, there seems to be an eerie silence (Maybe everyone is on vacation). After we finished our first round of instruction for the day in Bob Goff's shop, his wife asked him how we were doing. He said only one thing... "They’re certainly curious". That was the greatest compliment he could pay, and that's the idea. CZ

Number of Laps Used

Robert, The number of laps used would be four or five. I mentioned on a post to Preston that a set of laps of .5-inch diameter increments would be good, and .25-inch increments better. What I mean by that is .5 inches will do the job, and to spoil oneself .25" would make available more choices with more precision, but is not absolutely necessary. The particular progression of any one mirror decides which laps will be used and its not always the same ones. If we do more work than average with a particular lap I may skip a size. Generally the progression is one-half to one-inch increments on such a mirror. Having many more sizes is to be able to choose a very close match for any one session.

I'll give a sample set for the 12.5", although I can't tell you exactly what ones we used on the example mirror. We might start with a 7.25", then go to a 6.5, then a 6", then a 5.5" and maybe finish with a 5" if the 5.5 didn't bring the center down with the rest.

Sometimes it does and sometimes it doesn't. And if any one lap does more work than normal, we might skip one whole inch between sizes. That happens more commonly toward the center of the mirror. At this point I'm of the opinion that if someone invests in building a machine that along with that should go a full set of figuring laps, preferably aluminum. Once you have that available to you, you will certainly appreciate it. They last forever, as they don't wear out (the aluminum, that is).

I would make the smallest at 3.75 inches, and the largest at 60% the diameter of the largest mirror you wish to make. We have plans to do something that I think will be appreciated. We plan to document an entire mirror from start to finish. We're going to provide every minute of figuring work with every lap size, every stroke setting and offset position, with measurements as we did before. We're going to publicly figure the entire mirror from the sphere. This will take some time to do, because right now we're doing larger fast mirrors and I don't want to start with an example of a large optic at F/4.3, but would rather like to do something such as F/5 or slower, which means a 10" or 12.5" mirror. Be patient for that and in the next 90 days I expect to upload a documentation of the entire process. Thanks for your question. Carl

Carl, I think my problem is I have lots of questions. I just don’t want to ask until I have tried it myself. I need some time with a mirror and see what happens. That will tell me if I understood what was presented and how to use it. I really do appreciate everything you have shown. Well there is one question I was wondering. In the example-figuring sheet how many lap sizes were used? Robert

How we use the spreadsheet- set 7 and next lap size to use

Ok, let's look at set #7 and determine the next lap size to use. We want to work the region from 5.26" radius inward. Thus we must reduce the lap size, but how to chose the correct size. Disclaimer The following is just my attempt at trying to understand what Carl has given us and may be wrong. If we look at the diameter of the area to work we get 10.52", but we want the lap to be working this radius at its 80% working region. So

we should select a lap of 60%+ diameter of this region to work or let's say 6.5" diameter? Yes the precise (general) size is 6.3 inches so 6.5 it is good. Slightly larger is generally good; with slightly smaller you have to be careful of correcting the next zone in more than the one you're working on. Our 80% working region would be at the 2.6" radius of the lap. This would leave 0.65" extending beyond the area that needs correction and would be about 0.25" inside the edge of the mirror with a 0.25" offset.

Thus adjusting the stroke to traverse COC with offset to stop 0.25" on each side of the mirror will hit the area that we want to work. Yes, if I read all that correctly, you want precisely .27" overhang to generally correct that zone (.25" is fine). ***Now remember, the point of greatest correction depends on the offset.*** At closer to center it is more inward, and at more offset it will place it more outward. It is a sliding-scale kind of thing that you will learn from experience. However, we need to have some room to be able to vary the offset in order to keep everything smooth. More than that, we need to place some offset to get correction into that zone and do less work in the one behind it.

Notice the progression is slightly backward between the two zones. In this particular case you need more offset than normal to push the correction from the space between zones 4 and 5 to the space between 5 and 6. If we increase the offset from 0.25" to 0.75" in 0.25" steps every 1 to 2 minutes it will act as a larger lap. Not so much at that offset. It starts acting larger at 1" to 1.25 inches and further out than that. But if I remember correctly, moving a lap out with increasing offset moves the correction ***inward*** on the laps working action zone.

No, it moves it ***outward***. As you go away from center you're pushing more correction outward overall. Yet, we are not really moving the lap that far out so it should only provide a smoothing action and work the area just outside the 5.26" radius. I am guessing that because of this and in fact the area beyond the 5.26" radius is already finished, that we really want to have the lap working the 5.26" radius at the full offset of 0.75". So we need to set the offset to 0.75" first and then adjust the lap to 0.25" inside the mirrors outer edge at the end of both sides of the mirror. That region will not shift correction outward very much.

I'll give you a particular on this one (this is going to get detailed). Between .25 inches and .75 inches I'm afraid that standard overhang for the zone will correct the next zone in more than that one. Inside of 1" offset you will need to be about .25 inches further out, for a total of about 1/2 inch overhang. At the same time you need to shift some correction from the zone further in, so you will need offset in the session as well. In order to prevent correcting the edge zone more, as you offset through 1" to 1.25" and outward, you will then shorten your stroke length incrementally by 1/8". As you hit 1.25" inches you should be at standard stroke length. As you go out further on the offset, you would decrease by 1/8" inch and leave it at 1/8" inside of the given spot for stroke length. That is the sliding-scale kind of thing.

I apologize for the extreme detail, but Preston asked a very detailed question. It’s generally ahead of where we're at right now, so try not to be confused by it all.

How the Sweet Spot Works

In a nutshell, here is how the sweet spot works. For a 12.5" mirror, inside of about 1.25 inches offset the lap will leave correction slightly inside of the 80% spot, and outside of 1.25" offset it will deposit it slightly further out. All mirrors and laps have the same tendency, at about the same ratios. CZ

Underwhelmed with the Spreadsheet?

Hello Carl, all, Precisely, I can only speak for myself, but what I really need is a resume of the whole process. Keep in mind that this is nothing different than hand figuring with sub-diameter laps. The only difference is the machine allows us to measure stroke lengths and offsets, to get the process very precise. But it is NO different than hand figuring which has been done by ATM's for decades. For the sake of the exercise, let's assume I have a 20" f/5 mirror, fully polished and perfectly spherical, isn't theory wonderful ;-) First I have to make a 60% figuring tool, 12" diameter in this case, with Scalloped, Star, or "Normal" edge of the right temper?

You can start with a lap that is anything from 55% to 60% of the diameter of the mirror. A normal edge is fine, because the lap is round and you'll be moving it about a whole lot. We used to scallop our edges, which was fine, ***but have learned it isn't necessary***. A 60% diameter lap will have to be abandoned earlier in the process, and you would go to the 55%. The 55% will do the same thing slower and will go further than the 60%, and will save you making another lap, but you will need more and larger offsets to keep the surface smooth, and it will take a bit longer to do the work. Now, I place the 80% zone of that lap over zone 6 of the mirror, right? What would be stroke length in this case?

You would place the 80% zone of the lap past the ***EDGE*** of the mirror, because you have to correct the mirror all the way to the edge. 1/4" past the edge for the sweet spot is a minimum to get started, and my recommendation is 25% lap diameter overhang over the edge of the mirror to begin work from a sphere. You work at that place for a long time, moving among various offsets to keep the inner zones smooth, perhaps out to 2.5", or in that area. Then you watch the relationship between the two outer zones. When the outer zone is correcting a lot more than the next zone in, you decrease your stroke length, to balance it out. At some point the curve in the ML graph gets too tight, approaching what we call a "kink". (I pointed to one in the example). That's an indication a smaller lap is needed. On goes the machine until I get the required 0.070" correction between zone 6 and 7, correct? (Little random motion added) The rest of the mirror should remain not too far from spherical?

The rest of the mirror should look like the ML progression in the sample mirror. Let me depart here and talk to the whole group- *Let's get this understood, everybody*. All mirrors correct the same. All want to look the same in the progression. Faster mirrors are touchier, but they all work the same. The sample mirror will apply to any size and any F-ratio. The sample mirror in set one has a progression of 68, 70, 60, 40, 33, and 27% from edge to center. That is roughly how it should look at that overall correction. Faster

mirrors will have more spherical centers and slower mirrors will show correction further in more early on, because of the difference in slope between the faster and slower parabolas, but the overall curve of the ML graph will always look the same when it is being done right.

The key is to keep it smooth. So understand this- the progression outlined in the sample mirror is the same for EVERY MIRROR THAT WE DO. ***Look at he ML graph progression again, and again, and again, and again, and again, and again, and again. Get used to it! That is how you want your mirror to progress. When it is that smooth you're in "fat city".*** See the ML graph progress. See it again. Get used to it. Burn it into your mind. Look at the ML graph progression. That is what you want for your mirror. Look at the relationship between the zones at every stage of figuring. That is what you want your mirror to look like. ***No matter what size, what focal ratio, you want that smooth ML progression that is essentially the same as in the 12.5" mirror progression.***

The slower mirrors will get more correction in the center earlier on, and the faster ones will have less in the center early on, but the general shape remains the same. Go back and plug in the sets one at a time and watch that ML graph! Make a movie out of it, like flipping pages on a notebook. Make an animated GIF if you have to, but get it burned-into your mind. I can show you hundreds of progressions of the mirrors we have done and they all look the same, they all have smooth progression with more correction in the edge and less toward the center until each zone is done. That progression should answer every question on the desired relationship between zones for any mirror made. That is what we watch, and that is what you will watch, as well.

(Sorry for the redundancy, I hope I made my point)

When done, I move the lap to the next zone, number 5, and correct until same 0.070" relative to zone 6, so 0.140 relative to zone 7, and so on till I reach the center of mirror?

When starting out, which we did not cover in the sample, you will want to decrease your stroke length by 1/4" increments, or 1/8" increments. We'll show how to do that in the full progression sample in the future. Obviously you don't do the whole mirror at one stroke length, so when you're putting the rough curve into it, you want to randomize your stroke lengths. You might do 30 minutes at full 25% overhang, then 15 minutes at 1/8" further in, and 15 minutes at another 1/8" further in, and so on for four or five iterations. All the while you need to change your offsets to prevent zoning. Then you would go back and repeat. Then you measure, and adjust accordingly, either further out, or further in, as is needed. Of course I will have to use smaller laps for the center zones, as the outer edge of the 12" lap will reach the done zones and I don't want to touch these?

Yes, but only in part, because you can always reduce your stroke length. More importantly, you use smaller laps for the center zones because the larger lap will not parabolize the smaller area, it will make it spherical. The spherical aspect of the larger lap does not fit into the slope of the smaller mirror. Is that the plan? Please correct/add the wrong/missing elements. Well, in general, yes. But don't consider this a definitive course

as yet:) because its tough to give you more than that without actually doing one.

I guess what the group is in need of is a complete sample mirror process. The value in that will be that every mirror is done the same way. They all correct the same. Once you see it done from start to finish, you can apply the same principles to any mirror you wish to do. CZ

Figuring Concept

Let's see if I can get a concept across. Ideally, you would like the whole mirror to correct simultaneously, center to edge. That can in fact be done with smaller, long-focus mirrors, but not so with faster ones, and especially not larger, faster ones. I used to do 10" F/6 with one lap, and would watch the ML progression remain essentially a straight line until it hit the parabola. Well, a 50% to 55% diameter lap on a 10" at F/6 can do that. Interesting, we use between a 5" and a 5.5" lap to finish a 12.5" F/5, which is close to the same radius. After you do enough of these you begin to understand that what you're figuring is radii of curvature. You don't care what size and F/ratio the mirror is; you're working on a particular radius of curvature and a particular diameter. To correct the center in a 10" mirror at F/6.5 is the same as correcting the center on a 12.5" F/5. It's the same radius and the same diameter. You're going to use between and 5" and 5.5" lap to do either one. A larger one won't do it because the slope of that radius is too steep to be affected by a larger (spherical) lap. The reason a much larger lap won't do it is because of the difference in slope between the lap and the mirror. The deviation between the sphere of the lap and the parabola of the mirror depart at a certain point.

I'll give you an extreme example. The 8-meter mirrors that are made by the Mirror Lab in Tucson have a figuring lap three feet in diameter. But that figuring lap is made up of individual 6" laps, and each one moves independently with actuators. No lap on that larger substrate is larger than 6 inches in diameter. Why, because anything larger will not allow full correction of the mirror. The mirror is SO fast that the deviation between the parabola (or hyperbola, or whatever the final figure is) and its parent sphere is two millimeters in the center. That means the slope progresses a full two millimeters in surface height between the sphere and the finished conic. So anything larger than a 6" diameter lap of Gugolz 64 doesn't allow full correction of the slope.

Again, with a small, long-focus mirror you can do the whole mirror with one lap, because there is very little slope in it. I can figure an 8" F/7.5 with a 65% diameter lap from start to finish. I have to work carefully at it, but it can be done. But change that 8" mirror to F/4, with a radius of curvature of 80 inches, and we will need a 3.75" diameter lap to finish the very center. The larger lap will never change shape that much to be able to figure the slope into the center. So the reason we have different size laps is because we're figuring different diameters with the steeper slopes that most of today's mirrors have. The 7.5" diameter lap that will correct a 12.5" mirror at the edge will only leave the center essentially spherical. CZ

ML Graph is Used to Figure Mirrors

You're going to get tired of this. Some armchair theorists have deplored our use of the ML graph in the past, but that is only because they don't understand WHY we use it. The answer that should become patently clear over time if it isn't already is, because WE USE IT FOR FIGURING OUR MIRRORS. This is the big secret that we have never really said before this timeframe, but we are intimate with the ML graph, because it is a major key to the smoothness of our product. The ML graph has a "look and feel" to it that a wavefront graph cannot show you. You will come to the place where you know at a glance whether everything is in order or if you're getting messed up. You're going to get to the point where you take one glance at the ML at any point in figuring and you'll know without a second's hesitation whether you have a gem on your hands or a problem occurring.

It tells you everything you need to know, with the one exception of precisely where you want to place correction in a given session (which is the department of the wavefront graph). I'm really serious about this. Get intimate with the ML graph, and I don't mean to think it tells you what the mirror surface is doing, because it doesn't precisely do that. It gives you another kind of information, and that is relative percentage correction between all the zones. If you wish, sometime I can upload some full pages with a dozen ML's on each one, each being a particular mirror progression. The funny thing is, not one of them will deviate by any great amount from the one you already have. But maybe if you look at a bunch of mirrors all doing the same thing, the "gut instinct" will begin to take over, to the point where you "see" what it is telling you, at a glance.

The general trend is the following points for ideal ML progression:
1. More correction toward the edge and less toward the center
2. Keep the zones as close together in percentage as is reasonably possible given the focal ratio of the mirror, until you drop them one by one onto the line.
3. Keep the overall looking very, very smooth.
Any disjointed aspect shows zoning beginning to occur. In the example mirror, look at the difference between set #6 and set #7. Although not terrible by any description, #6 is beginning to get disjointed, and getting out of control. Then look at #7. THAT is the "look". That's the kind of shape and curve that you will come to admire and love. When you have that kind of shape that's when you will "feel good". Look at those percentages that accompany such a shape. That is how you want it to be. I'm up against another rather tough week coming up, or more like two or three. I may not be as talkative this coming week as I am right now over the weekend, so be patient, my postings if any, will be much shorter. Do what you can, and keep up the good work. CZ

John, thank you for your suggestion. I'm not sure four years for one mirror is a record, as Tom Noe of Teleport may hold it. My recollection is his first and only mirror took him some 12 years, or perhaps it was longer. But I do know it was more than a decade. That being the case he decided to hire a mirror maker for the Teleport instead of fabricating them himself. Those who are studying this method of mirror making will necessarily have made the investment in a machine that is capable of figuring as well as grind and

polish, which obviously warrants more than one mirror. My position on this issue is if one invests in a machine it is worthwhile to also invest in a set of laps. They should be significantly less in cost and labor than a good machine. But back to your point- I think it takes a true artisan to be able to depress facets and control one's surface slope with any precision. My hat is off to the mirror maker with such capability, as I believe that the craftsmanship and skill involved is no small thing. The judgment calls involved must be very sensitive. I admit I have not studied the art and practice of lap facet depression in any depth. I have on a couple of occasions doing hand work long ago tried my hand at a session or two, when I indeed did not wish to fabricate an extra lap (I think I used wax paper to make the depressions).

Your point is well taken, and I'm in agreement with you. It is a viable option for the optician who makes a limited number of mirrors, who does not wish to acquire excess tooling. At the same time, I'm really not practiced at the technique, and so as a result am not qualified to teach it. Thank you again for the suggestion, just the same. Carl

Carl: In my limited experience instead of making a whole new lap when doing one mirror, I used the old ATM plot of depressing some facets. (Cold pressing with paper on certain facets) I did not even think about making different laps for different zones, till I started reading this list. But, one reason for the "depressed facet" system is that as you work the depressed parts slowly come up to where they are working again which in my thoughts would generate a more gradual change of zones in the mirrors. I can sure see where if you were in mirror production of various sizes a whole range of laps would be useful or even necessary, but most of us are not going into competition with you by making several mirrors at once. (One at a time is plenty enough for this old man who ground his first mirror in 1943 and finished it about 1947, (IS that a record?)) John Meacham from the high deserts of California 8 inch f/6 Pyrex DOB, home ground, polished and figured.

An important point concerning measuring

Preston (and all students): An important point that may have not been mentioned at any time on this forum regarding measuring- When comparing measurements, always compare in the same axis of orientation. When figuring, always figure in the same axis of orientation. You can measure other axes to check for astigmatism, but always orient the mirror the same way when progressing through figuring, or when comparing test data with other optical shops. The only exception to this is if you're averaging measurements between two axes and figuring from that information. Even then, you use the same two or more axes every time. Don't ever assume that the mirror is a perfect figure of revolution, because it is probably not. It is rare that mirrors show only error of measurement in multiple axes with the knifedge, because the knifedge is so sensitive, and because mirrors generally are not that perfect in the revolution. Even in a mirror that has no measurable primary astigmatism it is common to have one or more zones off from the others in multiple axes, created by a hill or hole somewhere. If you reference that defect in one axis and use it for figuring, then when you move to another axis it won't be there. In short, do not randomly place the mirror on the stand in any orientation from one

measurement to the next.

We place one mark on the edge of the mirror with permanent ink. That mark is always top, and we always measure the mirror with that mark top, until we're rotating specifically for astigmatism data. CZ

I'm headed to Austin on Saturday to have a professional optics manufacturer measure the 12.5" f4.5 in its present stage of figure, to act as a bench marker for our test of the video Foucault. I am very interested to see what that testing says in comparing where we think we are presently. I will post the results on Sunday. Regards Preston

Figuring lap preparations

James, Thank you for the inquiry. This is a good and important subject, as outside of surface accuracy this subject is THE key to contrast. Let's go through it. Perhaps this is why my last 12.5" took 108 figuring sessions. Each time I'd find a nice parabola, I'd look at the rest of the mirror, cringe, and hear words like "inadequate polish", "rolled edge", "look at the tool marks", "dog biscuit", "micro-ripple" and so on. On that note, I was wondering if you could elaborate on your methods for preparing a lap for a figuring session. As with all things in optical fabrication, there are many methods that 'could' be used. Having looked at your optical surfaces, I know you've found a method that works, and works really well!

Okay, let's talk about the lap. We like soft pitch. We use Gugolz #64 mixed with #55 for our figuring laps, perhaps 25% to 33% of the #55 in the mix. The facets are relatively large and the channels are "relatively" small. This helps with primary ripple. I know you advocate wire brushing a lap. Do you use a small wire brush (tooth brush size) or a larger one and is it stainless steel or brass? Do you scrub the entire CEO residue off, or just enough to scuff up the lap? How frequently do you brush your laps?

There is no real residue of CEO on figuring laps because of how thin our figuring cerium is. After brushing however, any that may be left is gone. We use a full size brush intended for paint scraping, in most cases. Brass is fine, stainless steel is fine, but right now we're just using plain-old wire. As long as it doesn't stay wet all the time rust doesn't seem to be a factor.

What we do is a gentle brushing in two directions 90 degrees apart. I'll upload a photo of a lap. In the spreadsheet folder see the ZOC generated files. It’s in there. The lap in the photo is not a perfect example, but can give a general idea.

Do you do your lap pressing Hot or Cold? Depends on what you're trying to do. We don't press hot on the finish glass because it can sleek the mirror. We only cold press on finishing glass. The only reason to press hot is to change the curve.

When pressing do you use lots of weight or no weight? A six-inch lap can take 15 to as much as 30 pounds. It varies widely. What's more important is how long we press (or

not). The fact is, we brush the laps because it helps them track smoothly. We don't allow the lap to jerk in any one direction suddenly. The many fine facets of the brushed surface create a smooth action. It also helps to mitigate seeing primary ripple the actual size of the facets. We do feel that there is some benefit on the surface quality from brushing, as many more fine facets are working, as opposed to just the edges of each larger facet.

Do you press for a few hours, over night, on or off the machine? We press for a few minutes on the machine. We press until the lap tracks straight. Too short and the brushed lap moves erratically. Too long and it spins too fast because contact is back to a smooth surface. It’s a fine balance that you learn by watching the lap action.

Let me go into more detail- first we press our laps to be certain the curves match. That can take any amount of time depending on the situation. Sometimes a hot press on a ground piece of glass with the same curve is required. After we have the curve we want, then we brush and repress on the mirror that is finishing for just a few minutes. I'm going to make a short film clip (and start my learning curve to learn how to compress the data into something that isn't too large). I want the group to see the machine and lap in action. It is slow, and it is very smooth. I'll do that when I can. As an aside, I once used a lap with a sealed MDF substrate. I would press the lap and mirror over night on a table. The next day I would move everything over to the machine, and it was immediately obvious something wasn't right. I finally came to the conclusion that the substrate was flexing under the weight of the quill. The solution I found was to use only glass or metal substrates, and to do my pressing on the machine, with the weight on the quill.

Yes. Now...there is more to all of this. It isn't just the lap. Here is an additional list of items involved that contribute to smooth surfaces, besides the lap:
1. A smooth, even stroke of slow RPM's. 20 RPM's on the eccentric is nice. On smaller mirrors up to perhaps 25 is okay as well.
2. The fact that the quill always is in the center of the tool. This is obvious, but the machine doesn't miss on this one. It never puts pressure other than the center of the lap.
3. Soft pitch really does make a difference.
4. Quill weight- we think of our quill weight as in ounces rather than pounds and our overarms weigh from 15 to 32 ounces at the quill depending on the machine and we also have counterbalances as well. We generally don't weight the arms more than they already weigh. The lap only sees that many ounces on it.
5. Cerium quality. We use premium grade cerium mixed down very thin for figuring. Our raw mix that we ball-mill is 1/3 solids and 2/3 water. We take that raw mix after it is milled and mix that at one ounce of cerium to a gallon of water, so it is essentially 128 to one. Believe me it cuts just as fast as thick cerium.
6. Humidity. A humid environment helps prevent rapid drying along the edges, which helps primary ripple in the edge zones.
7. And the secret ingredient (because you mentioned rolled edge)- I wonder if anyone has noticed that we have said nothing about how to handle the edge with this machine figuring, and how to prevent turning it? I'll say at this point that I won't address it because we don't have to. I'll leave it at that for now. Got to run, try that info for now. CZ

Movie of Figuring

Okay, we put something up for the machine mirror makers to see. We have a 7-3/4 inch lap working a 14.5" mirror. The file is in the Mirror Maker's Spreadsheet folder, in the ZOC generated files. (I deleted the secondary spreadsheet folder, and put everyone's work that was in it out in the main folder, as it was getting confusing.) Loading the movie with both AOL browser and Internet Explorer, clicking on the .MOV file loaded it directly into the browser in each case. It may appear your browser is stuck, but what is probably happening is it is loading the movie. It will obviously take a while to load depending on your Internet connection speed. Its a rather large file for this site at 3.7 MB, so I'm not going to leave it up for a long time, it takes up too much space. Download the file if you want to keep it for reference. Turn the sound down, because it truly is not as loud as it seems. The digital camera that shot the movie apparently adjusts the ambient noise to its normal threshold. What you'll see is Chuck working a 14.5" mirror with a 7.75" lap with a little bit of overhang. He dispenses some cerium, and makes an offset adjustment. This clip gives a general idea of the table and stroke speed we use, the smoothness of the motion overall, and the rate at which the lap rotates under the quill due to the table rotation and brush condition of the lap. This is how it looks when we do the work, and is what I would define as essentially ideal for this size mirror and stroke length. These conditions along with what I described in my last posting to James creates the surfaces whose photos you have become familiar with. (Only a mirror maker could be entertained by such a film clip...) CZ

Slit Foucault Tester

I know I'm an hour late and a dollar short on this one, but I'll mention it for general info for those whom it may benefit. We have never run a direct path from the light source out through the slit. We always bounce it off a flat white surface, at a 90-degree angle. In the case of our present model the halogen bulb is housed in a triangular tower, whose backside is a 45-degree angle with respect to the slit on the front. That surface is painted enamel flat white, for very most dispersion. The light source is off to one side, so the only light the mirror sees has bounced off the flat white surface, which has much more even illumination than a bulb can generate. There are other ways to do it as well, even to using a polished needle as a dispersion tool, but the above is the way we do it and always have. CZ The WB KE tester has a flashlight bulb for a source. Even with a potentiometer in line to control the brightness, the pinhole size was excessive...and without the pinhole the filament was too large to get a fine contrast...or at least that's what I think now.

10 Inch F6.5 Progress

Robert, You have a nice curve, there. Yes, the edge needs some attention. I would use maximum stroke length of 1.5" and offset as necessary until the edge begins to catch up to the other zones. I think you and Preston have the right idea of pushing outward by one-minute intervals and spending more time on the outermost offsets as needed. Working short sessions is good because it will tell you how much offset and time to spend. You

can adjust it very precisely through short sessions and measuring, it is not hard to do.

Notice when you use a lot of offset that other zones will de-correct and push the correction outward. So if you use just the right balance (and it sounds like you're in the ballpark for technique as well as layout) you may be able to come in with a three-zone or maybe even four-zone even landing. What I mean is, if you balance your time between the inner and outer offset positions just right to keep zone plots three and four from fully correcting (or overcorrecting) you will bring the edge zone in and get a very nice match between the three or four outer zones.

Then it’s just a matter of finishing the center with a 5" (approx.) lap. You're going to discover that doing 10" F/6's is a lot of fun, because you will have CONTROL that you have never experienced before. Its an unreal feeling to be able to land four zones all at one time together on a long focus mirror. And it is not difficult because most of it can be done with a full-length stroke.

That reminds me; don't forget about shortening stroke length as part of this process when the time comes. It’s not necessary at this point, but may be later on, depending on how the curve progresses. I'll mention here that long F/ratio mirrors require less shortening of stroke length than others, and depending on lap size used, some don't need it at all. "Looking good" Carl

Group, I uploaded my 10Inch F6.5 Mirror Spreadsheet into the Mirror Maker's Spreadsheet folder under Robert Turner. I welcome any help to get this mirror corrected. Last night I worked a 6" tool running out to about 1.5" overhang. I set the offset between .25" - 1.25" and worked approximately 30 minutes. I guess my next attempt is more of the same until the edge gets corrected. Any comments appreciated. Robert

Ricardo makes a good request, here. If you were willing, Robert, this would be valuable information for the entire group. And keep in mind there are no wrong moves. We're all learning here, so if the mirror goes funny we can all learn why, and then work to move it back on track. My guess is, this is going to be so much fun for you that when you finish, you may consider messing it up and doing it all over again... CZ

Hi Robert, Would you mind keep updating your xls file with the history of your strokes (timing, tool diameter, length, offset etc.) so we can follow the progress and get some more experience? I can also build one animated gif showing the three curves going to their places, with a text about stroke data. Regards Ricardo Dunna

I worked two sessions today. The second session showed the most improvement. I worked .25" - 1.25" offset with more time spent at the 1.25" offset. Seems to be working the edge correction. Worked both session 10 minutes. Going to do more of the same as I continue. Robert

Robert, All is going well. I sanctioned your rather short sessions to allow you to experience getting CONTROL of your mirror. (When we're out of control the first thing

we need to do is slow down). The signs point to that being accomplished at this stage. Now we can state that 10 minutes does not do a lot *once the zones are in good progression*. When they're strongly out of order, a large diameter lap can do a lot of trading slope between zones and it looks like a lot is going on. But when the mirror gets to looking more like it should for the respective lap size, then the perceived effect is smaller. What you're doing when correcting the edge is taking the entire mirror down with respect to it and that is your job, now. This takes time. I'm going to guess from memory some 2.5 hours of machine time to rough-parabolize a 10" F/6. Now that you're getting some control over what is going on, you can increase your times in your respective positions as you choose. So you have learned some rather important things- Notice that the outermost offset does indeed de-correct the inner zones and push the slope outward. Now you also understand that the larger lap when offset will correct the edge of the mirror effectively. Notice also that every progression you have posted (that I've looked at, anyway) moves toward a smoother ML progression, each one progressively closer to the measurement set that I gave as an example some time back. Now you can put some more time into your sessions. Increase your times a little each session, as you're comfortable. Then as you approach that smooth landing that we all hope you achieve, you can shorten the times back down again.

A note to everybody: as I think about this situation and how well Robert has gained control I think it would be reasonable to suggest that if at all possible, that all new machine students start with a 10" F/6, or similar small, slower mirror. There is no way we could have such fast success in fixing for example an 18" in such a situation. The difficulty factor will be equal to the increase in area multiplied by an additional factor of faster F/ratio. It is truly that much more difficult, as I see it. My first machine experience was a 10" F/6 and I did and experienced a lot of what Robert is going through right now. It was a wonderful and positive experience, because of the relative ease of doing such a size and F/ratio. The early mirrors were unbelievable even to me in that timeframe. Such accuracy and smoothness was capable because of the relative size and slope. What I want is for machine students to have such an experience as their beginning. If that happens you will never go back, because you will taste a degree of control and finish excellence that is addictive. Carl

I just updated the file. I included one more session I did yesterday. I included all the sets that I have done on the mirror plus some explanation on what I did. I will keep closer track on exactly what I do as I go forward. Seems my last session did not make as much change as I thought. I think it is de-correcting slightly in the middle and just a slight correction change at the edge. Robert

Images of Zone 5 Null, + .001" (gray scale problem)

Preston, An observation and a nit-pick: Yes, something appears off in the plus and minus images, in that both have zone five darker on the right. The nulled image shows them closer to a match. And one "nit-pick"- the surface is a bit lumpy. We'll work on that over time. I don't mean to take you on a goose chase when you're working so hard, but just the same I'll mention I'm wondering how difficult it would be if you had the equipment to put

a regular digital camera behind the knifedge, like we do (right now we use an Olympus 3030). We get a pretty clear, true-to life photo. I must admit most of our focograms are done through a small telescope (2.5x), along with the camera at 3x zoom. Generally what I see through the telescope and camera agrees with what I see naked eye, although we don't use the setup to measure the mirror as in what you're doing. Probably your CCD setup can do that well. But to examine the mirror more clearly, a digital image with a magnification of about 8x shows a lot of detail. We don't have any conversion issues, as the camera produces a TIFF or a jpeg file that we examine directly. Carl PS the new arm on your machine looks rather familiar...

In looking at the + .001" image that I posted something has happened. On my saved image the right window is lighter than the left, but in the conversion from bitmap to jpeg to up load it's lost something. I noticed this yesterday when I posted the image of the machine top and tried to get the mask images and Foucault image uploaded, that they were much darker with a gradient. I downloaded the nulled image back to my computer of the Nulled Zone 5. Converted the jpeg back to bitmap and read the gray scale in K3CCD software like I usually do. The original image is a 75 and the image that I get back and converted is a 125... Don't know what to think, but don't take the images for what I am really measuring. Hope I've not totally confused things. Regards, Preston

Aluminum vs. HydroStone

It’s been a long time since I machine-figured with a Hydrocal lap, and it was small mirrors I was doing. There was a long while that we did nothing larger than 12.5". I would make a guess at 6:1 ratio for thickness. And I see no reason why the substrate can't be used. I don't know if you want to try thinner than that with your larger laps, but if you do, just take the necessary precautions, such as spread the weight out when pressing, and such things. You know how to handle and treat laps, I'm sure. Just be gentle with them. There is no unusual amount of weight used when figuring, so they should be okay.

Carl I have a question. I fully understand the importance of having a stable substrate to use in the figuring laps. I do have a small amount of 1/2" thick aluminum, but not enough to create all of the lap sizes 4" - 12" in 1/2" increments. My sheet is about 18" x 18", and I plan on making a few laps out of this sheet, but I do not have the budget at this time to invest in more aluminum, especially not at the $4.69 per pound the local scrap yard and nearly $100 per square foot for 1/2" thick sheet the local aluminum distributor is charging. With all of the handwork I have done, and taught in our telescope making classes, we have always used HydroStone to cast a base for the polishing lap. The diamond curve generated mirror is used to cast a curve in the face of the HydroStone, and then the disk is stored until time to make the pitch lap. Are there any major problems when using HydroStone to make a backer for a figuring lap? HydroStone is similar to HydroCal, which Carl has mentioned, in a previous post, similar to Dental Stone, with the main difference being that HydroStone is harder than the others once cured. If HydroStone will make a good lap substrate, how thick should it be cast to minimize flexure and give good figuring results? John R. Zeigler

Sounds like you have your lap process down. It is a sign of a lot of experience. We now use ball ends on our quills with all our aluminum. What we did with our HydroStone and such kind of tools in the past was a compromise. We used 1/2" bolts with threaded ends for the quill, and put a "swivel foot" on the end. There are different kinds; ours always came from catalog orders. Some were from Grainger and some from MSC (both US-based companies). A swivel foot has two or three parts to it. On the top it threads onto a bolt, on the bottom is some kind of a foot either mainly flat or cylindrical, and in the middle some kind of spherical bearing. So the rotating/bearing action was in the swivel part, which required periodic lubrication. In the tool substrate we would put a bronze sleeve bearing and some epoxy or resin in the end. That held the foot in the tool. Go to the spreadsheet folder in the ZOC files and see a photo of "swivel foot". Another possible method given your ball end quills would be to construct a hub that accepts the ball end, and inset it with epoxy to the substrate. Of course, one hub would be necessary for each tool; there is no getting around it. The payoff for machine performance is tooling cost. It took us several years to get everything up to speed, and we still have stuff to upgrade even today.

One more thought. You might get away with just drilling a hole in the HydroStone and epoxying a bronze sleeve bearing (they are oil-impregnated) in it the size of your ball-end. You can buy bearings that have shoulders on them and are a particular length. Pour a little resin or epoxy in the very bottom, or epoxy a small washer in the very bottom. That should last as long as the tool does. CZ

My main concern with HydroStone tools on the machine is with the socket for the machines pin. I know that I will need to put something in there so I do not tear up the hole or pin. But what would I use to connect the lap to the machine. (The pin is 3/4" diameter with a ball end). John R. Zeigler

Large Aperture Mirrors

Hi, John O.K. Out of necessity, my first machine mirrors will be a 12.5" f4.5, 18" F4.5, 18.75" F4.5, 24" F4.3, and a 24" F5. "Necessity"? Goodness, you have ambitious plans. Any way I can harness some of that energy? (Smile). I have to admit if I had such necessities two years ago we would be sunk. What I don't know here is what apertures you have experience with prior to attempt at any machine work.

I would be interested to know the largest aperture you've successfully finished to date, and perhaps how many of them, or mirrors in the size range. Speaking from frank realism, it took us no less than a full year to learn how to dependably finish a 24" mirror. That was after doing some 30 each 20" mirrors and a few 22's as well. Its not that we didn't know how to figure one, it is rather that handling the glass and keeping a figure of revolution becomes exponentially more difficult with the increase in aperture. And I mean EXPONENTIAL. I'm speaking to everyone when I say this; a mistake that many amateurs make is thinking they can get the same results with an 18" mirror as they can with a 10", because they successfully completed the 10".

Now John, I know you have a lot more experience than that, so it will help me to know where you're at right now with apertures completed. I also have a 10" F6 I may use as a test piece of glass to get the kinks worked out of my machine. I think that's a REAL good idea. And not just for the sake of the machine, but for the entire process. I think we need to learn the basics of machine figuring. As far as help from this place, it will be helpful to do things one-step at a time. These parameters I've outlined don't go up the scale at same numbers.

We ***don't*** use a 60% diameter-figuring lap on a 24" and for good reason. We also ***don't*** spin 24's at 60 RPM. And as far as machinery goes, a machine doesn't handle a 10" mirror the same way it does a 24. We have three sizes of figuring machines (other than "Lurch" who is in semi-retirement). We have two that do from 7" through 14.5, we have one that we use from 12.5" through 20" and one we use for 18" through 24". The largest machine is some three times heavier than the smallest. It has heavier components that I would not put on a 10" mirror.

Half of these mirrors are already polished out, as I have put in time working them by hand while I was finishing up the machine. The other half are curve generated and are ready to start fine grinding. As I understand the machine polishing process, I need to use a lap that is around 75% the diameter of the mirror. I will spin the mirror around 60 rpm on the turntable, position the lap so it has a maximum of 28% overlap at the end of the stroke and I will stroke the lap on one side of the mirror so it goes between ~25% overlap to about 3/4" overlap. These numbers are good for 10" and 12.5" mirrors. The RPMs may need to slow down a bit as the mirrors get larger, or at least, at the finish of the polish. The maximum overhang is 25% lap diameter.

After polish is complete we slow the speed way down, brush the lap so it squeals like hell, and feed our finish cerium on it. After two hours of finish polish we run approximately 1-hour sessions (what we call "squeal sessions"), then look at the figure of revolution. If you do this with slow table speed and a well brushed lap you will see that it removes residual astigmatism that may be left from beating the mirror so hard at the fast RPM. Once the mirror is completely polished out and has a nice figure of revolution close to a sphere without any major zonal defects, then it is ready for figuring. I will then start with a 60% diameter lap following the techniques covered on this board over the past few weeks to figure the edge of the mirror and work towards the middle of the mirror reducing the size of the lap, stroke and offset appropriately.

Am I on the right track here? Yes for the 10" and 12.5", but when you go larger than 12.5" and on to faster mirrors let's talk about your beginning size for figuring laps. Let me mention something here for everyone. It is not critical that we start with a 60% diameter lap on larger and faster mirrors. That size will do the most work the fastest, but will have to be abandoned at some point. That point depends on F/ratio. With very fast mirrors you will have to go to a smaller lap somewhere around 60% correction in the edge. In very slow, smaller mirrors you can fully correct the edge with the 60% lap. If you're doing a fast mirror and want to minimize the number of laps you have to fabricate and use, you can start with something smaller, such as 55% to 58%. It will take you

further into the process.

The mirror I plan to use as my public example is the 18.75" F4.5 mirror. This particular mirror is one I am making for the GE Betz Science Center Boy Scout Camp in PA. I want to be certain that they are getting the best mirror I can make them, and see this project as a great way to achieve that.

Sounds great. So can we practice on something slower and smaller? I should also say here that the first two hundred mirrors I made commercially (and which made my reputation) were no larger than 12.5 inches in diameter, and no faster than F/5. That's where I practiced and perfected the art. THEN I went to larger and faster mirrors, incrementally, and still had a lot of trouble and learning curve, to make the zonal progression smooth. It is not easy, even for the accomplished optician, to make a large, fast mirror. Doing fast mirrors is not easy by any process. I strongly recommend learning any figuring technique as thoroughly as possible with slow and small mirrors. Then work up, one step at time if at all possible. Otherwise, we risk stumbling all over ourselves. My goal is to have the first set of test measurements posted by the end of the weekend. I will keep a log of the entire process so everyone can see what stroke, offsets, time, lap size were used, and what the results were between each step. I am certain that I will make lots of mistakes, but I am eager to learn from them, as I am sure everyone else will by making them public. Sounds wonderful.

And it’s easier to fix mistakes on a 10" F/6 than an 18" F/4.5. In fact, you can essentially refigure one in a day. (Sorry for "harping") My second goal is to have this mirror finished so I can field test it at our class star party on Sep 10th. Which mirror is that, now? I know that this is a very ambitious goal, but I've got to give myself a deadline otherwise it will never get done. I don't recommend making any promises to anyone regarding delivery date on a totally new process with a large and fast optic, on an unproven machine. How 'bout we learn this process for a while, then set some goals based on actual results. John R. Zeigler Carl

Laps

I've been waiting for someone to make that offer. (Go, Bob!) Keep in mind a little thickening of the substrate would be in order at a couple of diameter increments. Carl

Hi all, I am just trying to catch up after being unable to participate for a couple of weeks...jeeeez!!! I don't think I will be able to make much contribution to this discussion as you all have progressed way more than I thought and I don't have the available time to work through all the information here. Carl, this is really a great discussion with more information available in one spot than can be gleaned from most books on the subject. Thanks for sharing it with the world. Now one thing I may be able to help with, I see lots of discussion on laps and lap sizes. I have a machine shop that is looking for small jobs and it has two Hass CNC milling machines.one 15 horse and one 20 horse just sitting and not being used. I can see what the cost would be for machining disks in 1/2-inch increments, say from 4 inches out to 10 inches diameter out of 1/2 inch thick plate. They

could also have a recess for a poker pin machined in the center (specify the diameter and depth) or a set of tapped holes to mount a poker pin receiver onto the disk, your choice. If several out there would want to pool their resources (financial) and order several sets of disks, the cost savings could be substantial. Let me know if there is any interest and depending on the response, I will get an estimate for said disks. See you, Bob

I'm rather busy at the moment, but when it comes time to actually do the job, I can dial the parameters in tighter with quill suggestions (we have a nice setup here) as well as a better thickness progression (the present progression is on the thick side). For now, I suppose the present info is good enough for bidding purposes. CZ

Preston, Thanks, I'll use these as a guideline for the job bid. At this time I will get a price for the disks alone without any additional pieces such as a receiver for the poker pin. I am looking at requesting the center of the disk be marked by touching it with a small center drill leaving a dimple about 1/16th inch diameter and only a couple of thousandths deep, enough to show where the center is but not so large or deep as to be intrusive. I didn't mention before that I am not making any money on these. Just acting as a facilitator so the cost will be limited to the materials and the machine time and shipping. The estimated cost will probably be within 10% of the actual run cost or at least that has been my experience so far with this shop. I'll be talking to the shop today but we still have time to add items like tapped holes for receivers in some sort of standard pattern on each disk, although that won't be included in the initial bid. See You, Bob

Lap preparation and theory- trimming and dressing ZOC-style

Carl Thanks for the lap photos. Shows the quality and uniformity very well. It also has generated some questions. You are trimming you laps by hand with a razor but how are you generating the original channels? With a small framing square right after I pull the tape off the edges, which is when the pitch is hard enough to stay on the lap but soft enough to press grooves into. Then we press it onto the glass to set up. The grooves close up, but their lines are still in place and they help to make channeling easier. (I always wanted to be a "channeler"). So we basically cut the entire facets by razor blade. Takes about 5 minutes for a lap that size...(uh, when one has some practice under their belt). I see this Aluminum disk is about 3/4 inch thick. It appears to be sitting flat on the surface. Do you have a hub that attaches to the back for the quill to ride in or is the disk recessed to accept the quill and if no hub how deep? If you have a hub can you share specs with us?

Quill has ¼ inch Ball End

No hub used or needed. Our figuring quills have 1/4" ball ends on them. A hole is drilled slightly larger into the aluminum, deep enough so the ball doesn't jump out. Works just fine. A larger recess as a safety catch is okay too, but we don't happen to have them on our figuring laps. We do have them on our larger polishing laps, however, as there is a lot more speed and pressure in play. In our folder in the Mirror Maker's Spreadsheet folder in the files section look for a jpeg called "lap and quill". A lap might be used on a mirror for several days or weeks. How are you storing them? We store laps pitch face-up on a

shelf and nothing on top of them. On warm days they can slump a bit. We have theorized that if we wanted a Gugolz lap to store indefinitely we would put it in a tub of water so it can't outgas. Never tried it, though. When the pitch needs to be replaced do you recycle it?

Reuse Pitch

No, we don't like to temper it. We would rather spend a few bucks to have a precise and predictable consistency. For our (commercial) operation this is not where we want to pinch pennies. An amateur on a tight budget may wish to do otherwise. I think recycling is okay to do, as long as everything is kept reasonably clean. Anything special required other than keeping it from becoming contaminated? Not that I think of off-hand. We just wash and brush the laps well when reactivating after being on the shelf awhile. For Gugolz we watch it carefully at 4 months for hardness characteristics. At 6 months we toss the pitch and pour a new lap. The hardness will have changed enough that its characteristics don't work for us, unless we want to try to use it for rough polish. Harder pitch is okay for that, sometimes. Sorry to be so inquisitive but I know your system works and a lot of the information I have gleaned from the web has not worked for me. Everyone has a different system. What I find in cases is an amateur may try something once and it seems to work. That process or technique then becomes the "Bible" until it doesn't work the next time. Then they scramble to find something that does, and that becomes the "new Bible". There are a lot of Bibles on the web. The difference here is we have standardized our system based on thousands of iterations. So what we do stays pretty much predictable within its appropriate boundaries. Thanks Dave I'm glad you're inquisitive. Carl

I'm pleased to be corresponding with you John Meacham, and even more so to know there is some serious competition out there. My best wishes for another fun ride as you embark upon your next mirror-making project. I just hope it doesn't actually take seven years this time. Oh, and if you get such a machine up and running again similar to your description you have made for us, I would be delighted to see a photo of it. Carl is it a deal? OK Carl that’s a deal. Thanks But since the tube was made from a chunk of Sonotube that had been left in the rain, I do think I will keep the mirror as is and build a new scope around the optics. (The old scope did not do too well on its trip in a moving van either) I built that scope out of wood (I didn't have much metal working tools at that time) But now I have a lathe and milling machine so have ordered a new piece of Sonotube (not from the local lumber yard this time) and the glass cloth to make it stiffer (have epoxy resins left over from my wooden boat building adventures) I put the ball bearings on my Crayford focuser too far apart so will correct that also. Spider is too flimsy and I have to collimate every time I take the scope out to the back yard. I did the mirror on a machine similar to what is in ATM volume 1 pictured as Lee's machine. Except instead of a rocking link (marked H in the book) I ran the main arm across my workshop about 8 feet through an adjustable guide to simulate the straight line motion of hand working. (No "W" stoke there) but I figured by hand after the donkeywork was done. I deliberately made my ratchets "sloppy" with irregular teeth so as they rotated mirror and tool they would never follow the exact same path again. Now I can be in competition with your shop, nothing faster than f/6 and five to seven year delivery time (I am almost 80 now so don't rush me) and of course with that time frame my prices would

have to be much higher. LOL. I think we all appreciate the time you take to assist and guide us amateur glass pushers, Thanks again. If anyone is interested in rolling their own optics they are in for a real thrill the first time they turn even a mediocre scope up into the sky, even the moon. That first light sight is sure to knock their socks off! I can still remember the thrill I got at my first sight of Jupiter and Saturn with an instrument I made myself. (The "Seven Sisters" too will shake you up with your first scope) That was a plate glass 6-inch f/8 done back in the 1940s. (Still can't find what ever happened to that scope.) Hope one of my kids has it someplace, and was not sold off or thrown out by my ex-wife along with most of my tools and hobby stuff. John Meacham from the high deserts of California 8 inch f/6 Pyrex DOB, home ground, polished and figured.

Lap Area of Most Effect During Figuring

Preston, your recollection is correct, however allow me to elaborate a bit. First, a disclaimer: Any such principles as we're stating here are fairly broad generalities. There is no one "point" where the work is done; the lap does different things everywhere it comes in contact. Keep in mind also there are variables involved, such as lap size with respect to the area being worked on, offset from center, and pitch hardness. Given all that, performing roughly a back and forth stroke across the mirror when the lap is approximately 60% the diameter of the area you're working, the lap will deposit the majority of the correction at 80% radius of the lap where it is positioned at the end of the stroke.

When the stroke is more across the center, this deposit point moves slightly inward. When the offset is more away from center it moves slightly outward. When the relative lap size is reduced, that point also moves inward, and when it is increased, it moves slightly outward. When the pitch is harder the tendency is for the correction to move outward, and when the pitch is softer, more correction will take place further in. There are other variables as well, but those are the major ones. It is this information that allowed me some time back to say to Bob K. on this forum that doing the stroke he did for an extended period of time with "x" size mirror and "x" size lap would create a zone precisely at a particular radius.

He verified that analysis, which shows it does have some predictability. And the key as you already know is, don't stay in one place too long :) CZ

Hi Carl, in trying to remember 3 hours of constant conversation, I seem to somewhere in the deep recesses of my mind remember you saying something about a part of the lap that does the most work. And one should position this area of the lap over the zone on the mirror that one is trying to reduce or work. Even more specific, I think it was the 80% radius of the lap. Or was 3 hours just TOO much to soak up for this old man like you who now see's only silver on the floor at the barber (gray is a 4 letter word.....Bad). Regards, Preston

Bob Goff used A-arm machines for mirror making as well. He had one for sale when I was there, a 50" that was custom designed and built. (That’s fifty inch). Looked like a

real big Strasbaugh. The company Strasbaugh has been making mirror-grinding machines for many, many years. When you look at their catalogue it looks like something from WWII. Well, it probably is. The design has not changed in all those years, because it works. You noticed a couple of mods that we have done to the design for our machines here, they are specific to our process. But the overall function is same. CZ

Thanks for the dissertation Carl; the learning curve is ever growing. I now also see why you start from the outside edge and work in toward the center. We've been working the OD edge but cannot do a stroke center over center with the lap edge overhanging the opposite edge by 20-25%, as by design our eccentric throw is less than 1 and are not big enough to do that pattern. Thus in trying to sweep the outer zone only with a 24% overhang with a 7" lap we dug a deeper hole in the center. Once you get the edge correct, you can leave it alone. Corrected with a 5" lap working the OD zone not touching the center. I'll be modifying the machine this weekend to encompass the best of both designs. I like your overarm :<) Preston

Images of Zone 5 Null, + .001" (gray scale problem)

I'm seeing the same surface near the edge as well; it is evident at the bottom, in the photos. If you wish to work on surface smoothness at some point let me know, I can make up a punch list for you. Otherwise we'll go on with the rest of the exercise and talk about surface smoothness when you don't have other items in play. I do realize that measurement is the key issue right now. There is in truth, many factors that have to be maintained simultaneously to fabricate a premium optic. And most of us do best working on one at a time. I know it is certainly the case for myself. Carl

Carl, You My Friend can Nit-Pick all you want!!!!!!!!! And yes, I do see a little bit of bumps...in the inter area, but overall it seems smooth... Preston

And one "nit-pick"- the surface is a bit lumpy. We'll work on that over time. Carl PS the new arm on your machine looks rather familiar...

Time for me to get started

Yes, I do have ambitious plans. I have done a lot of mirrors by hand, perhaps 100 or so. The majority of these have been 12" and under, but I have done a few larger mirrors up to 18". The 24" mirrors will be my first. I can get surface qualities around 1/20 wave as calculated by TEX or FigureXP, but lately, I have primarily been doing ronchi tests until what I see on the mirror is between perfect and 1/8 wave error as displayed with Ronchi for Windows error mode. I like how the ronchi image can immediately show me gross surface errors during polishing so I can adjust technique as needed to achieve or maintain a good sphere until the mirror is polished out.

That's impressive work. A 24" mirror is a different animal than an 18. One major factor is the necessary constraint on thickness, unless you want a mirror that never equilibrates. That thickness constraint challenges us with a ratio that is much thinner than the norm,

and this is coupled with the largest aperture we will deal with. We spend a lot of time with every step on a 24" mirror, and we take great pains to cater to its thickness ratio. I also have a 10" F6 I may use as a test piece of glass to get the kinks worked out of my machine. I think that's a REAL good idea. I keep going back and forth between starting with the 10”, which needs to be ground still, and the 12.5”, which I have polished out by hand and am ready for figuring.

One of the most powerful aspects of machine work is the ability for it to polish out mirrors. A machine can put labor into a mirror that we cannot with any reasonable amount of energy. I have spoken to this issue before, so I'll keep it short this time. I would not hesitate to put a hand-polished mirror on machine to continue the task, even after it is optically polished out. When working by hand a major issue was scratches. We always had some sleeks and scratches, because we could not provide the stock removal or the consistency of power than a machine can. Imagine 60 RPMs on a small mirror for twelve hours without stopping. What happens is the glass gets to a point where scratches don't recur (except in the case of abrasive being spilled on the mirror). Our mirrors now have no scratches as a rule, as well as only a rare occurrence of sleeks. The glass is polished so well that the substrate doesn't "catch" abrasives. And as far as machinery goes, a machine doesn't handle a 10" mirror the same way it does a 24. We have three sizes...

Well, at this time, this is my first machine. I do have the base for a second machine, and I will most likely build it to be a dedicated figuring machine, and use this particular machine primarily for grinding and initial polishing. I'm referring to aperture. The machine that can effectively figure a 24" mirror may not be the right system for handling a 10", which has smaller laps and could use more delicate treatment. Now I have some time before I have to have the 24" mirrors completed. But one of the 18" mirrors, I need to get done fairly quickly. This particular mirror is in payment for a bunch of machining I "Horse Traded" for the construction of my Big-O-Matic style articulated arm, and I received the arm three months ago, but since that time, we have had some serious family medical emergencies and were victims of identity theft. The machinist understands the setbacks, but I need to get this mirror completed so I can meet my part of the bargain. So I will start with the 10" or 12.5" mirror. Then I would like to step up to the 18" mirrors. I know that there is a learning curve here, but I am up to the challenge. So what size lap should I use for the initial polishing and figuring on an 18" F4.5?

Understood. I'm going to make a suggestion. Being as you have a specific time constraint I'm going to advise that for this one 18" mirror you may want to seriously consider continuing with the "tried and true" method. You have experience with making them successfully by your current method, and it is not an unknown to you. When it comes to deadlines and time constraints that may be the better path.

I must say something here pre-emptively, on this subject. ***I'm not willing to accept any notion of responsibility for my direction in finishing any specific number of mirrors by parties on this forum, especially those which have a deadline or are used as payment for goods or services.*** I have a business to run as well as a house that is in major remodel

right now (currently my optical work is slightly behind schedule). I'm willing to provide information and specific help to ATM's on their projects for mirrors for which they have no specific deadlines. I'm willing to help ATM's learn about this process with their current project mirror. Another way to put this is, I cannot guarantee that I will be available at every point needed in figuring large, fast mirrors, nor can I guarantee that any mirror will have a successful finish by this method. There are too many variables. And, there is more than one ATM on this forum that is working on a project. I need to be careful to not add further pressure to myself by teaching specifically in a commercial venture that has deadlines.

As long as the student accepts those terms and all responsibility for their own projects, I can continue to provide guidelines as able. So what size lap should I use for the initial polishing and figuring on an 18" F4.5? We polish with a 75% diameter lap, which has been discussed on the forum on this subject before. And in my last posting to you I discussed in some detail starting sizes and considerations for figuring laps.

Well, I guess I am jumping the gun a bit. I am around 100 mirrors, mostly under 12" diameter. But I am ready and eager to start working the larger mirrors. That's thoroughly appropriate, in my mind. Nothing wrong with that at all, at the same time I personally need to avoid deadlines and too much time spent on the forum. I require a relaxed pace to best serve the mirror group, and that includes some days away from it occasionally.

Believe me, you are not harping. You are sharing your hard earned experience. I have spent the past two years teaching telescope and mirror making classes and have had over 75 students in four classes. I have learned A LOT teaching these classes, and I can see many areas where I need to increase my skills at, and it just happens that this project started right at the time we decided to take a break from teaching classes so I could bump my skills up to the next level and to devote the time to our little business so it can grow.

Hopefully I will soon be able to come home from the office and make telescopes and mirrors full time. This started out as a hobby / obsession, then turned into a small business which my wife runs while I go to work to earn enough money to pay the bills. I can see so much potential in our business if I could just put in the time to do it right. I am so grateful that you have offered to impart your knowledge to the ATM community.

You're going to love machine figuring. I know you're anxious to proceed at full speed. I'll do what I can given our circumstances. Which mirror is that, now? Well.... That would be the 18.75" F4.5 mirror. I have it polished out and at a rough parabola. It has a little astigmatism (less than several commercial mirrors I have tested) to work out before final figuring, but this mirror is very close to being a finished mirror. It is also the thickest in relation to the glass diameter (1:11 to be exact, or 1-5/8" thick Pyrex)

Worth mentioning- I can only advise on a figure of revolution. You choose the axis of measurement, or, combined average as you wish, and I will advise on that particular information. I ask that it be the same axis or combination in each iteration.

The above-mentioned goal of having the 18.75" mirror done by the 10th of next month is only a personal deadline. The mirror does not need to be completed until spring of next year when the Boy Scout camp builds the observatory. As far as deadlines for customers, the first three mirrors need to be the 12.5", a 16" I forgot about before, the 18", and one of the 24" mirrors, although the 24's I have 3-6 months to complete. I guess I was thinking that since I have the 18.75" rough parabolized that I could start on the figuring right away, and with it's size that I would learn a lot. However, I have no problems starting with the 10" or 12.5", preferably the 12.5" mirror.

The 12.5" is fine; we're doing that size with Preston. I appreciate your candor. So, this is a bonafide commercial operation you have. A note to everyone on this subject- Please understand that I'm advising on technique for the purpose of learning how to figure on a machine, and how to read the spreadsheet and interpret results and apply technique. This in no way sanctions any particular mirror as being to any particular standard. In other words, once a mirror appears to be done by the numbers someone has posted, we cannot necessarily state that it has any "stamp of approval" other than the mirror maker who fabricated the optic. Once again, thank you so much for your willingness to share your knowledge. You're welcome, John Carl

John, I appreciate your reply. I should clarify my intentions in one paragraph. I'm not unwilling to help professionals learn technique, and they are welcome on this forum. I'm also happy to help you on any mirror you wish to do, paid or not. What I'm avoiding is being caught in any particular project, which would depend on my giving a specific set of suggestions for its completion. That means deadlines and I may not always be able to be there when needed. Also, what could happen is because of this being a learning experience a project could get bogged-down. It is not unusual for that to happen. For example one might do just fine on a 12.5" but then learn the machine is entirely unfitted to work an 18. Such is entirely possible, we know well about such situations. So as long as I'm free to reply when able, then it’s fine by me. You're welcome to participate. Thanks, Carl

That being said, I will be involved or un-involved in the classroom training, as you desire. I will continue to work with the spreadsheet team as I feel that I have a lot to contribute to that project and the ATM community. (I explained our commercial nature and interest in my introduction to the spreadsheet group, but I think Rich pulled your email from the Spreadsheet group before I sent that email). However, since I am working on mirrors for others, I fully understand if you do not want to offer specific advice for these mirrors. This is the main reason I first chose the mirror I am making for the Boy Scout camp as my public example. This mirror is being done without any payment of any kind. I have already procured a GEM for their project similar in size and capability of a Paramount ME, and we have received donations of all the major components to build the scope. I am building the scope and acting as their technical advisor on the project. Personally I would not feel right getting you to hold my hand while figuring a mirror I am getting paid to make without compensating you for your time. So, if I were to list the mirrors I am working on which I am not receiving any payment or services of any kind for, that would be the 10", 12.5", and the 18.75" mirrors. The other mirrors on my list are

either for pay, or trade for services. So I will no longer mention any of those mirrors on this board. I will only mention my own personal mirrors, or those I am donating to a good cause such as the Boy Scout observatory. Once again, thank you so much for your time, expertise, and willingness to teach the ATM community the techniques you have spent many years learning. John R. Zeigler

I hope that the information we give back is used to elevate the whole of amateur astronomy- from ATM's, to professionals, to the end user. Carl I am amazed at your willingness to share your "Trade Secrets" as that is what you are doing. These are secrets you have learned during the process of making thousands of mirrors, and by all rights, this is your intellectual property and you would have every right to keep them secret within your own doors. Once Again. Thank You. John R. Zeigler

Five zone spreadsheet available (was: 10 Inch F6.5 Progress)

Group, I was so busy that I failed to acknowledge that Robert apparently single-handedly constructed a five-zone version of the spreadsheet so he could upload his information and get comment. Way to go, Robert! I didn't go over it with a fine tooth comb, but by all reasonable appearance it looks like he stayed absolutely true to form with the original. Nice going. So, for those of you who need a 5-zone, we have one in the Robert Turner folder. So at present we have a seven-zone and a five-zone. That will do a lot of sizes of mirrors. They're not international version, but for those who really do want to use them and don't mind making the conversion from metric on the inputs, it can be done. Thanks, Robert. That was splendid. Carl

How to Achieve Surface Smoothness?

Okay, since you asked... Based on empirical results something is amiss. The surface by any description by an optician who is striving for a premium mirror is lumpy, regardless of how few in number it is. I have seen this kind of surface before, more from amateurs than professionals. Professionals who have rough surfaces usually are because of speed, and they have systematic gouges in them. I'm not certain of the cause of your surface; so let's check some things out. The moon rises in the east and your ancestry is not changeable, so let's talk about your cerium.

Cerium

I would like to know what kind you're using (brand and type), how it is prepared, mixed, poured off, or what-have you. I want to know the final ratio mix, water-to-cerium. A cerium mix that is too rich can have an effect such as what I'm seeing.

Eccentric Speed

I want to know your eccentric speed. How many RPM's is the eccentric actually turning when you figure?

Lap

I want to see an actual photograph of your figuring lap. Strangely arranged facets or poor

pressing, or flexing tools, or too-small facets can cause problems. I would like to see the lap that produced that surface.

Weight on the Quill

I want to know how much weight you have at your quill, that is, how much is pressing down on the lap. I want to know if your overarm is free-floating. Is it on a hinge that puts no more pressure at the end of a stroke than in the middle? Some machines have an air bladder on them (I know where this idea came from and it wasn't from an optician). Such a tool has no place in figuring, in my estimation. The overarm needs to be putting no downward pressure from other sources (such as hydraulics), other than the actual weight of the arm, and it needs to float freely. That is, if you lift it with your finger, it goes up and down and is the exact same weight as it hinges. We'll start with that. Carl

Ok Carl, Let's discuss surface smoothness. Other than moving the offset regularly, very thin cerium water ratio, a brushed well pressed lap, slow turntable speed and faster overarm speed...good humidity (not a problem in Houston during the summer, 75% an 80 degree F in the shop)...no extra weight on the overarm, pitch on the soft side, the moon rising in the east, and being of Italian ancestry...what else is important? Now this should be very interesting so see other things that contribute to surface smoothness I'm seeing the same surface near the edge as well, it is evident at the bottom, in the photos. Yes, now I see that also. But these are also very few in number overall If you wish to work on surface smoothness at some point let me know, I can make up a punch list for you. It is important in the overall scheme of things, so we might as well learn the aspects now so that it will be second nature. Regards, Preston

A "PS" on the surface smoothness question. Looking at it again, we call it an "oatmeal" surface. I see it at just about every null point that the mask allows light to go through, but is best seen on the bottom. From what I can tell, my guess is the entire surface has the "oatmeal" finish on it. That reduces contrast. But don't despair, we'll figure it out.

Wet Surface

One more point- you have to keep the surface very wet when figuring. You don't want it to dry out at all. CZ

I'm going to leave the cerium as an unknown for now, it sounds like you're doing a good job with it. If you do a lot of work in the future I would consider buying a name brand premium grade such as ZOX CE89 by the gallon from Salem Distributing. It is pre-mixed and easy to work with. From your information at this point I'm looking at the lap condition as the most possible culprit. I'm assuming the lap looks as when you use it. It needs dressing. The channels have a wide variance in them. For example rows three and four from the left on the top half are rather narrow, compared to row 5 from the left, which has some rather wide spaces. This non-uniformity can cause a non-uniformity of flow rate, which will leave some places higher than others. Such could cause the surface I'm seeing.

Number of Facets

Also you might want to consider on your next pour to make even larger facets. Its not

absolutely necessary, but we have migrated to less facets and I think it may help. We have only four channels and 5 facets across on our 7.5, same as our 6.25 whose picture we uploaded. Look again at our lap. It does need a slight bit of trimming, but the channels are fairly uniform. What I need to do is photograph a lap that is perfectly trimmed and ready for work. I'll see to it soon. Everything else seems reasonable at the moment. So I would concentrate on the lap. The more you can make it look like one of ours; I would say the better the possible results. Carl

Preston's Facts

Okay, since you asked... I would like to know what kind you're using (brand and type), how it is prepared, mixed, poured off, or what-have you. I want to know the final ratio mix, water-to-cerium. A cerium mix that is too rich can have an effect such as what I'm seeing. The cerium is from Newport Glass- no number on the bag. It is mixed 1 tablespoon in 1/2 cup of distilled water and let set overnight. Then that is mixed into the remaining gallon of distilled water. The next day, the gallon is mixed again, and let sit for 20 minutes. The top 3/4 of the gallon is siphoned off into a clean jug. This is used for figuring. I want to know your eccentric speed. How many RPM's is the eccentric actually turning when you figure? Turntable speed is 3 rpm's and the eccentric is stroking at 15 strokes per minute. I want to see an actual photograph of your figuring lap. Strangely arranged facets or poor pressing, or flexing tools, or too-small facets can cause problems. I would like to see the lap that produced that surface. Lap picture is in my file. It weights 3.4 pounds. I want to know how much weight you have at your quill, that is, how much is pressing down on the lap. Weight on tip of quill is 2.2 pounds. I want to know if your overarm is free-floating. Is it on a hinge that puts no more pressure at the end of a stroke than in the middle? It's just like yours. We'll start with that. Carl
Best Regards, Preston

A question from Carl/ (Is your mirror worth $50.00?)

John, I don't understand being given a choice between a regrind and a recoat unless the issue is three scratches. I doubt they will change performance. As I understand it you made this mirror a long time ago, and spent a great deal of time and energy on it. Let me ask you a question- Is the mirror as it sits right now worth fifty dollars to you?

If the answer is yes, I have a recommendation. Don't regrind it. Because as soon as you take grit to that mirror the long hours of work and the energy you spent are gone forever. They just disappear. You will never again be able to look at that piece of glass with fond memories and tell the story of what you did with it, because you will have erased the evidence. The history will disappear.

Here's where I'm going with this- if you have a real itch to play with glass again, sell the mirror to yourself for $50.00 then keep it! Don't ever work on it again. Take the $50.00 and buy another blank. You should be able to get a good 8" blank for that price. Then play with it. Spend all the time and energy you want on it, mess it up as many times as you wish, experiment as many times as you like, because you will "always have the mirror you have now, and it only cost you fifty bucks to keep it!" Is it a deal?

Okay, if you promise me you'll do that I'll tell you about temperature and humidity. Villain #1 is temperature. The huge swings between day and night in unconditioned space wreak havoc on a pitch lap and how it behaves with the glass. If your pitch is soft enough you might survive it, but I really recommend that after grind you do what you can to get into conditioned space for the polish and figure. Humidity is not that much of an issue for an 8" mirror, especially for handwork. It really is more of a factor for TOT figuring by machine, and more important as the sizes get larger. Carl

Carl: Just in case I totally lose my mind and decide to regrind and polish/figure my 8-inch f/6 mirror again what can I do about temperature and humidity here in the desert? Of course temperatures range from the 100s with the humidity such that you cannot spit on the ground; it evaporates before it hits. But at night as soon as the sun sets it gets cool enough (I would guess low 70s or so) to need a jacket. Then naturally I can't do this in the house around the animals and the SWMBO (She who must be obeyed) where it is air conditioned, The work would have to be done in one of my sheds (The garage contains her kiln and pottery wheel, and stored thingamabobs) The sheds are well insulated, but not heated or cooled although I can get a portable swamp cooler to place in the doorway. Or would I be better off just to get the mirror stripped, re-aluminized and cover the three scratches with a black sharpie pen? Thanks in advance John Meacham from the high deserts of California 8 inch f/6 Pyrex DOB, home ground, polished and figured. P.S. I was not living here when I originally did the mirror.

I've uploaded a new photo of a 7.5" lap that I was using today on a 14.5" mirror. Actually it's two photos in one, of the same lap. Look for "dressedlap" in the ZOC generated files in the Mirror Maker's Spreadsheet folder (the 6.25" lap photo has been eliminated, this takes its place). The photo on left is the lap after being trimmed with the razor blade. Note the uniformity of the channels. The micro facets (angled cuts that change direction) break up the larger facets and provide more cutting surfaces. They also allow even more uniform pitch flow. Then the photo on the right is the same lap just afterward, the difference being it has been brushed with a wire brush. Note that it is wet from the brushing, and that it doesn't reflect light in the same way. It appears darker because of all the tiny grooves left by the brush (The surface is no longer shiny). Brushing also rounds off the edges a bit, which is not really an issue one way or another. Think of a well-dressed lap as a tire that requires traction for good driving. You would not want to run on bald, or smooth tires. The tread provides even, stable tracking on the road. Good tread means good driving. Perhaps it is an analogy for the pitch lap. Some theory- Imagine we have uneven channels in our lap. Couple that with a slick pitch surface and we will have "hard contact" between some areas of the lap and the mirror. What I mean is, uneven channels may cause uneven pitch flow, which can result in hard contact in isolated areas. This is the setup that I suspect can cause the "oatmeal" look. Now I like lumps in my oatmeal, especially in Cream of Wheat (love to chew on them!). Perfectly smooth Cream of Wheat is boring. But perfectly smooth mirror surfaces are not. So let's try for "no lumps" on the mirror. Now lets go back to the photo. The lap on the left has the curve of the mirror. It is a good match, but realize the surface is a bit slick. When we press a slick surface we will have "hard contact" that may not last too long once we start moving it

around an aspheric shaped glass. The lap may behave erratically in a short period of time, and it may produce a surface that is not desirable. However, after brushing, the entire surface has thousands of tiny grooves of about the same amplitude in it. The pressing sequence following the brush flattens out the tops of these grooves to create uniform overall contact, but does not eliminate the grooves altogether. So what we have as a result is the entire lap is a surface of tiny edges all in uniform contact. I'm going to call this "soft contact". It is full contact over the whole lap, but the tops of all the tiny grooves form the contact, and it is in a sense a softer contact in nature. You can push on the tiny edges and they give a bit, but they don't disappear right away. I think this is what helps produces our uniformity of contact as well as surface finish. When these grooves are pressed just the right amount, the lap will track uniformly for a prolonged period of time, up to an hour and more depending on circumstances. Note that these grooves will be much taller than the aspheric slope in the mirror, so I think they allow more movement over a longer period of time, keeping uniform (read: smooth) contact. (Also note here that this discussion is about machine figuring of mirrors, as opposed to handwork where you can control the spin of a lap much better with the hand) Interestingly enough, if we press the brushed lap too long and flatten the tiny grooves back out, the lap spins too much and will again move erratically. Is that a result of poor contact? No, I think it is more a result of "bald tires". Go figure. CZ

Zone 6 still a problem, Spreadsheet update

Lap contact is absolutely essential, as well as consistent measurements. In looking through the iterations is appears the edge zone for example changes from greater to lesser correction back and forth. That concerns me a bit. I also think you're having contact problems.

I would like to see a longer initial press. Here's what to do. Trim your lap so it’s in superb shape and press it for a couple of hours to make *certain* you have full contact (fill the bowl of the mirror with water so it doesn't dry around the edges). One way to tell if you have contact is to turn the mirror and lap upside down with lap on bottom, and gently move the mirror around a bit on the lap. Wet the back of the mirror so you can see through it. You can see with the cerium in place on the lap which facets are in contact and which are not. Then after you have full contact brush the lap and do a short press to prepare for figuring. If you read back through my general parameters I think I instructed on offset and general characteristics. I would have said something like...

When the offset is inside of a particular radius the correction will go more toward the inner zone, and when the offset crosses a certain radius the correction will begin to shift outward. Apply that principle to this situation. When you don't have correction far enough out there are three items other than good contact and proper technique.

Really there are only two, and those are stroke length and offset (the third is lap size, but you can make up for that with offset as well). So if your stroke length is at full maximum, then you must turn to offset to solve the problem. After the lap prep I suggested, lets do something to correct this, but not too much all at once because given your variables

(whatever they may be), I'm not seeing the results I expect. Again, I think it may be that the edge of the lap is not in contact with the mirror. I do recall you have a warm shop. The lap can slump in as little as 24 hours. If that is the problem, then another iteration same as before should begin to correct the problem. We can do an extreme measure to correct, but then you might think that is normal protocol and get confused. I'll give you the extreme measure and let you do with it as you choose, for one iteration, only: With a full length stroke, start the session with the offset at 1.25 inches. Do one-minute increments increasing offset by 1/8 inch until you reach 2.5 inches offset. That is 11 minutes. Do this two times for a total of 22 minutes machine time. Let the mirror equilibrate for no less than three hours, and better yet overnight, then measure it and report back. Carl

Hi Everyone, Well as you can see, I have been busy. Lap contact and proper surface reared its ugly head a few times. Overall it seems to be progressing, but zone 6's defect is baffling me. I think that it was a low spot, but I just cannot seem to bring it into line. The new spreadsheet update is in my file, and the most recent work has comments as to what was done as far as lap size, overhang, offset, duration, pressing weight and time, brushing etc. Comments are welcome. Thanks, Preston

Preston, Let's do this one-step at a time. Scrap the previous iteration instructions about the figuring session. I have never seen a 60% diameter lap in full contact leave a center fully corrected and leave an edge alone. Get your lap in full contact and do another one of the same kind of sessions as before, with offsets in the same range, from 1/4" to 1.25 inches. Spend at least 20 minutes at it. Do whatever it takes to make certain that you have full contact edge to edge on that lap. Carl

Ok, I'm on board with this one... I will press for 1 hour...Check the lap, and go from there...as far as trimming, brushing etc. Could it be that I have the Cerium water mix TOO thin...it is currently about like ice tea...and at the end of a iteration, when cleaning up...most would think that there was little if any cerium involved... No. Correction is going into the mirror. The pattern is a classic for using a smaller lap than the one indicated.

My guess is that in 80-degree heat it is slumping. It is possible there has never been full contact. ...And 17 pounds is not necessarily enough. Press the lap until the very edges show that they are beginning to close up. Immediately afterward trim it, brush, then short press for the session. If you're concerned about your cerium being too thin I can give you a guideline, which is good for the compound, we use. Mix 33% solids by volume solution (1/3 cerium, 2/3 water by volume). Then take one ounce of that solution and mix with a gallon of water. Then filter it. Because with all the decanting you do we have no idea what your cerium content is. Carl

Carl, I read your description of the polishing and figuring lap construction and application (Thank you) but I have a question about contact and flow. If I am polishing with a pitch lap per your instructions will the channels close fairly evenly or will I see the center close up faster than the edge? What about when I am figuring. The center channels

always close up ahead of the edge channels in both instances.

It is a common occurrence; expect it to be that way in all cases. If it is not too much trouble would you post a picture of a lap after the session but prior to Re-trim, Polish or Figure? The lap photo on the left side before brushing is what a figuring lap looks like after an average figuring session. The top gets a bit shinier. We don't trim figuring laps so often. I may use one four or five times before trimming, but we brush it lightly every time. Polish is another story. The lap works for many hours at higher speed and under more pressure. The facets smooth over and the channels close down more. Think of the facets as being completely smooth over their face. That's what it looks like after polish. Let me know if you need more information than that. Carl

Ok, let's see what I did:
1.) Made up new cerium per instructions. It works as I now have 5 more micro inches to remove. Went from 49 in the last session to 54 now. The reason you have more micro inches to remove is because the center is rising now, as it should. That may well continue until the edge is corrected.
2.) Pressed lap for 2 hours with 25 lbs. Channels closing at edge, so trimmed all of lap. Temperature in shop is 79 degrees F. I can see all facets in contact through the back of the mirror. Good
3.) Brushed and pressed for 10 minutes with 17 lbs. Good
4.) Maximum overhang 2" at 1.25" offset. Offsets of 0.25 to 1.25", were moved every 60 seconds starting with 1.25 and working inward. Once at 0.25", moved out to 1.25" and started again. Did 5 iterations for a total of 25 minutes. That is precisely backward. We're trying to push the correction *out*, not in.
5.) Let it cool for 6 hours before testing. The lap after being worked for 25 minutes is very evenly worn across all facets. The brush marks are still visible but very worn. Good.

That variable is now under control. Aim to always be aware of that, because the condition of the lap is paramount. The lap is what creates the surface. New update is in my file, but zone 6 looks just the same. Comments most welcome...I think I've been here before. I already made my comment. Next session, and we'll adjust out one step. I recommend a repeat of the procedure starting at 1/2" offset, and moving outward 1/4-inch increments to 1-1/2 inches. Do four iterations, as you did before. By the way, what is your ratio of table to overarm (eccentric), precisely? It should be between 5 and 6 to one. Unpredictable results will occur if your lap is rotating too fast and in the same direction at the edge as the mirror. When you're trying to push correction out you want to increase offset during the session. Obviously, when you want correction further in you move toward the middle. Think of the surface while you are working- where are you removing glass? If you understand where you are removing glass your intuition should tell you where in general to move that lap. What is going on right now, Preston? Are we establishing a baseline? I don't know all your conditions there unless I'm actually on site witnessing everything going on. It can be difficult to be able to absolutely troubleshoot and completely control anyone's results. Up until this last iteration we did not know whether your lap was in contact. That is as major a condition as it gets. Once I have a feel for your result given a particular iteration, then we can begin to adjust. I'm still looking to get you to duplicate

the session that I would do here on your mirror if it were in this shop. We're not there just yet, because we have to cover every single variable that exists, AND do it all simultaneously.

What happens is that over time, the optician learns each variable one at a time and begins to do them automatically. Then results become more and more predictable, and we can go where we want more at will, and with fewer "train wrecks" :) At best this process will require an unusual amount of patience. The accomplished mirror maker will have an easier time switching to machine because they already understand the general principles and techniques of mirror making. But the new mirror maker will have the added complications of getting a machine to do what they want it to do as well. Carl

stop 3129